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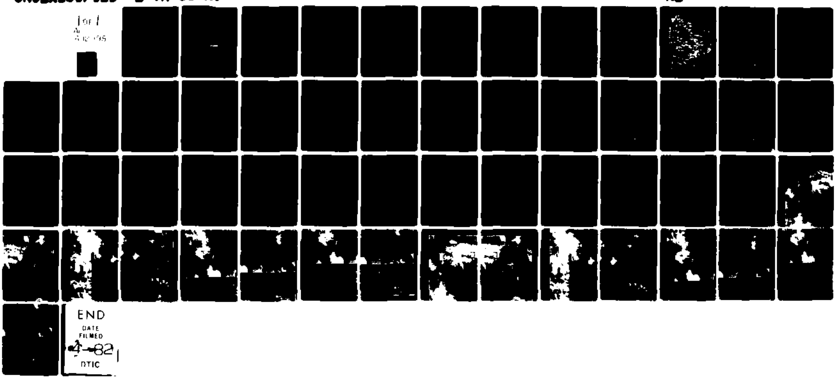

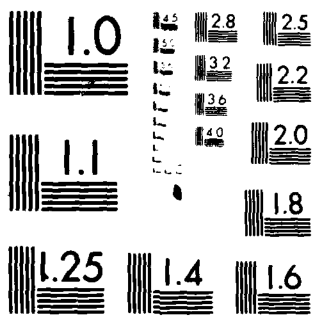
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GRAVITY SURVEY - RALSTON VALLEY

NEVADA

Prepared for:

U.S. Department of the Air Force
Ballistic Missile Office (BMO)
Norton Air Force Base, California 92409

Prepared by:

Ertec Western, Inc.
3777 Long Beach Boulevard
Long Beach, California 90807

20 August 1981

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20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Gravity data from Ralston Valley, Nevada, were studied for the purpose of making a geological interpretation which includes estimates of the overall shape of the structural basin, the thickness of alluvial fill, and the location of concealed faults. These estimates are expected to be useful in support of fault studies, in modeling dynamic ground motion in response to nuclear detonations, and in evaluating groundwater regimes.

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FOREWORD

Methodology and Characterization studies during fiscal years 1977 and 1978 (FY 77 and 78) included gravity surveys in ten valleys; five in Arizona, two in Nevada, two in New Mexico, and one in California. The gravity data were obtained for the purpose of estimating the gross structure and shape of the basins and the thickness of the valley fill. There was also the possibility of detecting shallow rock in areas between boring locations. Generalized interpretations from these surveys were included in Ertec Western's (formerly Fugro National) Characterization Reports (FN-TR-26a through e).

During the FY 77 surveys, measurements were made to form an approximate 1-mile grid over the study areas, and contour maps showing interpreted depth to bedrock were made. In FY 79, the decision was made to concentrate on verifying and refining suitable area boundaries. This decision resulted in a reduction in the gravity program. Instead of obtaining gravity data on a grid, the reduced program consisted of obtaining gravity measurements along profiles across the valleys where Verification studies were also performed.

The Defense Mapping Agency (DMA), St. Louis, was requested to provide gravity data from its library to supplement the gravity profiles. For Big Smoky, Hot Creek, and Big Sand Springs valleys, a sufficient density of library data was available to permit construction of interpreted contour maps instead of just two-dimensional cross sections.

In late summer of FY 79, supplementary funds became available to begin data reduction. At that time, inner zone terrain corrections were begun on the library data and on the profiles from Big Smoky Valley, Nevada, and Butler and La Posa valleys, Arizona. The profile data from Whirlwind, Hamlin, Snake East, White River, Garden, and Coal valleys, Nevada, became available from the field in early October 1979.

A continuation of gravity interpretations has been incorporated into the FY 80 and 81 programs, and the results are being summarized in a series of valley reports. Reports covering Nevada-Utah gravity studies are being numbered "E-TR-33-" followed by the abbreviation for the subject valley. In addition, a more detailed report of the results of FY 77 survey in Dry Lake Valley and this report on Ralston Valley were prepared. Verification studies were continued in FY 80 and 81, and gravity studies were included in the program. DMA continued to obtain the field measurements, and there was a return to the grid pattern. The interpretation of the grid data allows the production of contour maps which are valuable in the deep basin structural analysis needed for computer modeling in the water resources program.

The gravity interpretations will also be useful in Nuclear Hardness and Survivability (NH&S) evaluations.

The basic decisions governing the gravity program are made by BMO following consultation with TRW, Ertec Western, and the DMA. Conduct of the gravity studies is a joint effort between DMA and Ertec Western. The field work, including planning, logistics, surveying, and meter operation is done by the Defense Mapping Agency Hydrographic/Topographic Center (DMAHTC), headquartered in Cheyenne, Wyoming. DMAHTC reduces the data to Simple Bouguer Anomaly (see Section A1.4, Appendix A1.0). The Defense Mapping Agency Aerospace Center (DMAAC). St. Louis, Missouri, calculates outer zone terrain corrections.

Ertec Western provides DMA with schedules showing the valleys with the highest priorities. Ertec Western also recommended locations for the profiles in the FY 79 studies with the provision that they should follow existing roads or trails. Any required inner zone terrain corrections are calculated by Ertec Western prior to making geologic interpretations.

TABLE OF CONTENTS

APPENDIX

LIST OF FIGURES

TABLE OF CONTENTS (cont.)

LIST OF DRAWINGS

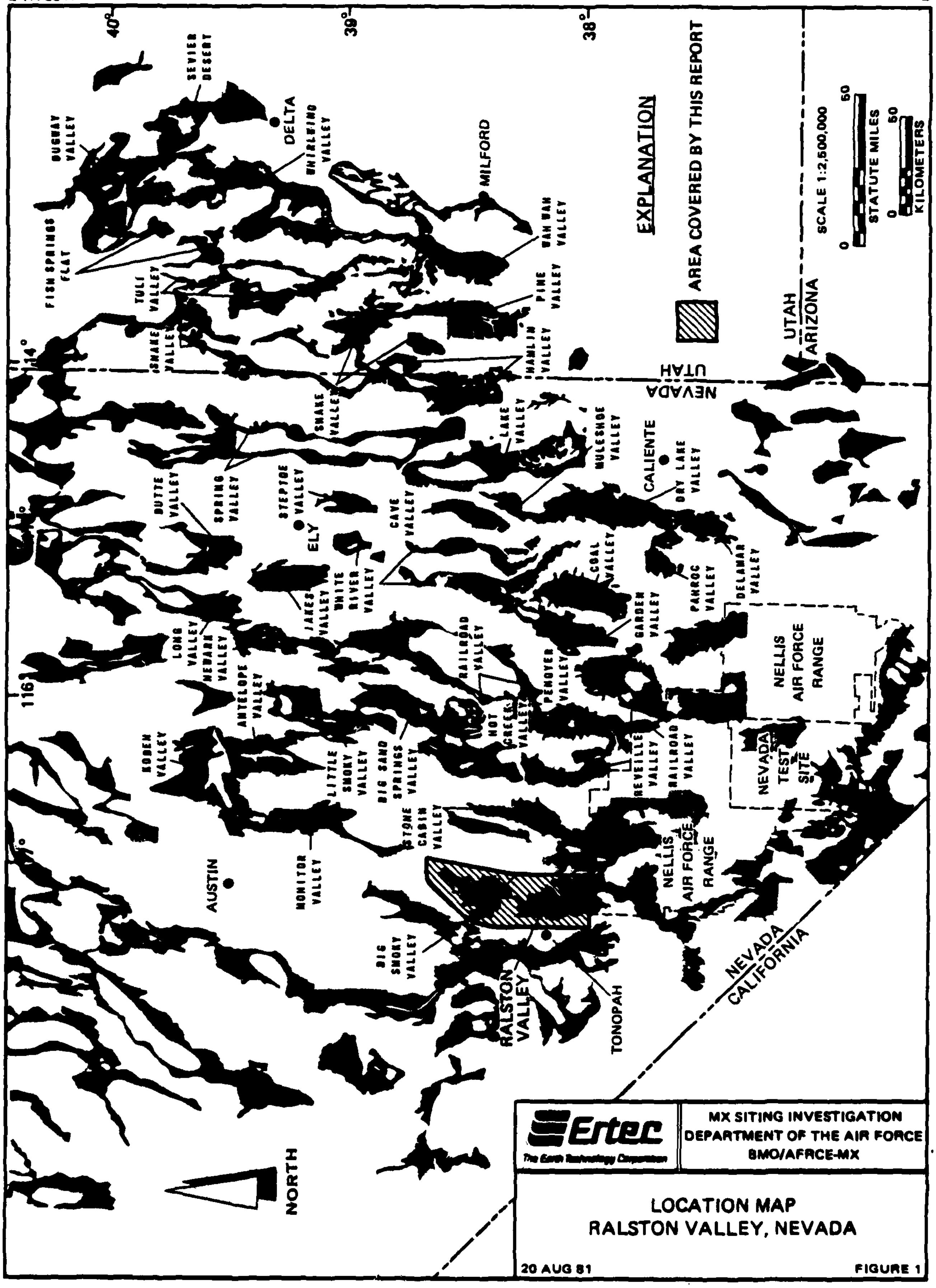
1.0 INTRODUCTION

1.1 OBJECTIVES

Gravity data from Ralston Valley, Nevada, were studied for the purpose of making a geological interpretation which includes estimates of the overall shape of the structural basin, the thickness of alluvial fill, and the location of concealed faults. These estimates are expected to be useful in support of fault studies, in modeling dynamic ground motion in response to nuclear detonations, and in evaluating ground-water regimes.

1.2 LOCATION

Ralston Valley is in southwestern Nevada, immediately east of Tonopah, as shown in Figure 1. The valley is bounded on the west by the San Antonio Mountains and on the east by the Monitor Range and the Monitor Hills (Figure 2). The valley is bounded on the north by the Toquima Range. The study area is bounded on the south by the Nellis Air Force Base Bombing and Gunnery Range. The valley becomes very narrow between the Midway Hills and Thunder Mountain, approximately 15 miles (24 km) northeast of Tonopah. U.S. Highway 6 and State Highway 8A provide paved highway access through the valley, while graded roads and four-wheel-drive trails provide access within the valley. The area covered by this report lies between North latitude 37°45' and 38°35' and West longitudes 116°45' and 117°15'. The valley is approximately 7 miles (11 km) wide and 48 miles (77 km) long.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LOCATION MAP
RALSTON VALLEY, NEVADA
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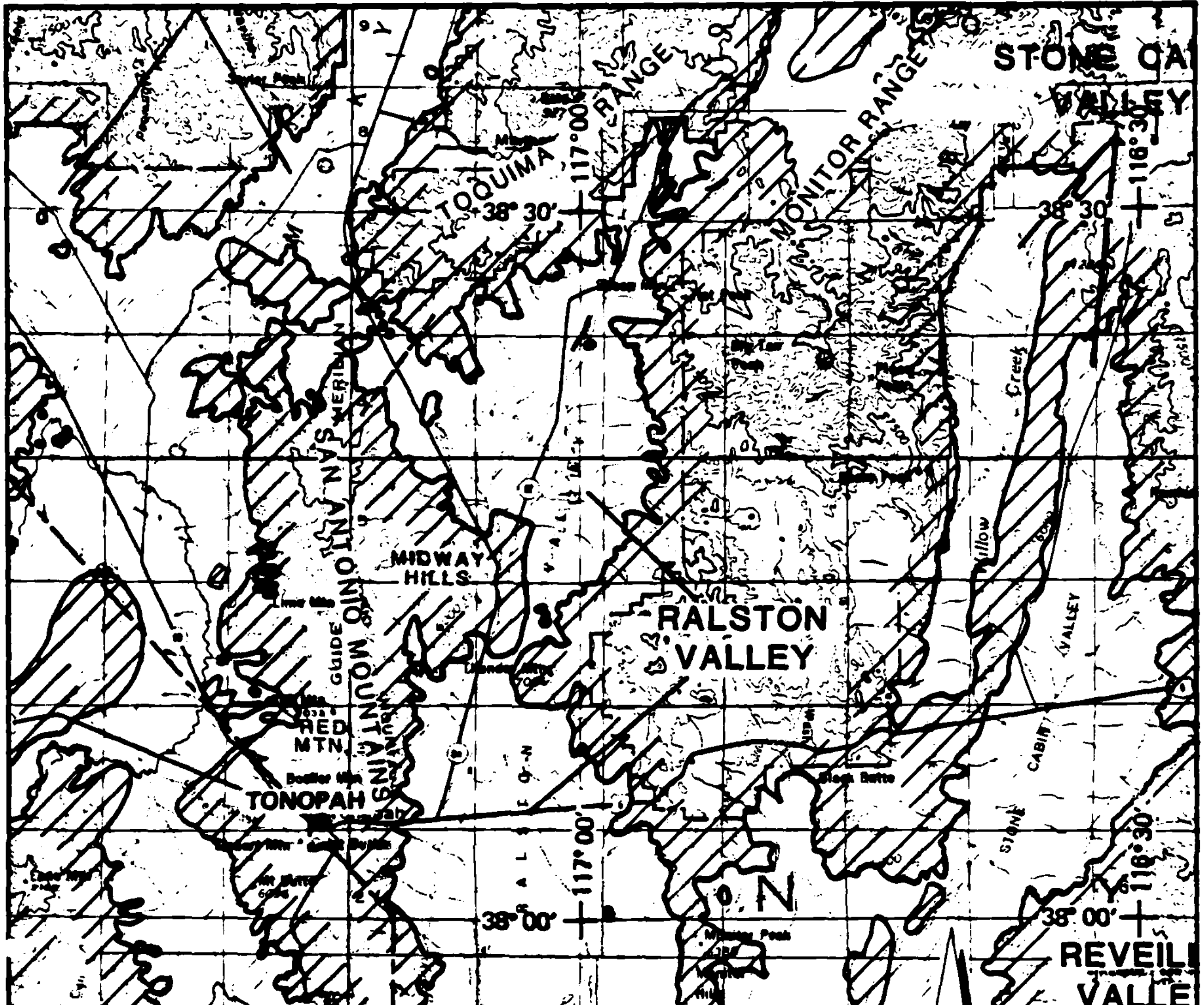
FIGURE 1



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TOPOGRAPHIC SETTING
RALSTON VALLEY, NEVADA

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FIGURE 2

1.3 SCOPE OF WORK

Five primary work elements were completed during this study. They are:

1. Computation and merging of terrain corrections;
2. Synthesis of regional and valley-specific geological data;
3. Evaluation of the regional field and residual separation;
4. Inverse modeling to estimate depth to bedrock; and
5. Interpretation of structural relationships.

Two sets of gravity data form the basis for the interpretation presented in this report. The first set contains on the order of 900 gravity measurements which were made at approximately 1.0 mile (1.6-km) intervals in the southern part (south of latitude 38° 15') of Ralston Valley. These measurements were made by the Defense Mapping Agency Hydrographic Topographic Center (DMAHTC) during 1977. The second set of data is from the Defense Mapping Agency Aerospace Center (DMAAC) library. This set contains about 550 stations which form the basis for the interpretation north of Thunder Mountain. Compared to the data in the southern part of the valley, this coverage is sparse and less systematic.

2.0 GRAVITY DATA REDUCTION

DMAHTC obtained the basic observations for the new stations and reduced them to Simple Bouguer Anomalies (SBA) as described in Appendix A1.0. Up to three levels of terrain corrections were applied to the new stations to convert the SBA to the Complete Bouguer Anomaly (CBA). Only the first two levels of terrain corrections described below were applied to the library stations.

First, the DMAAC used its library of digitized terrain data and a computer program to calculate corrections out to 104 miles (167 km) from each station. Second, when the program could not calculate the terrain effects near a station, Ertec used a ring template to estimate the effect of terrain within approximately 3000 feet (914 m) of the station. The third level of terrain corrections was applied to those stations where 10 feet (3 m) or more of relief were observed within 130 feet (40 m). In these cases, the elevation differences were measured by DMAHTC in the field at a distance of 130 feet (40 m) along six directions from the stations. Ertec used these data to calculate the effect of the very near relief.

3.0 GEOLOGIC SUMMARY

Ralston Valley is located within the Great Basin section of the Basin and Range physiographic province.

The dominant rocks exposed in the mountains surrounding Ralston Valley are Tertiary volcanics (Bonham and Garside, 1979; Stewart and Carlson, 1978; and Cornwall, 1972). Of these rocks, Tertiary welded and nonwelded ash-flow tuffs predominate, especially in the Monitor Range on the eastern side of the valley. Andesitic and trachyandesitic flows and rhyolitic domes form extensive outcrops on the western side of the valley (Bonham and Garside, 1979). Small outcrops of Cretaceous and early Tertiary age granitic intrusions and Paleozoic limestone, shale, and sandstone are scattered throughout the San Antonio Mountains and the Monitor Hills and probably underlie the Tertiary volcanic rocks. The basin-fill deposits consist of sand, silt, and gravel accumulated under alluvial fan and lacustrine conditions.

The last major volcanic episode in the area occurred in middle Miocene time when the trachyandesitic flows of Red Mountain, Thunder Mountain, and Mud Lake were extruded (Bonham and Garside, 1979). These trachyandesites comprise much of the Midway Hills and Thunder Mountain, which effectively divide Ralston Valley into northern and southern halves.

The Basin and Range block-faulting tectonic regime began prior to the middle Miocene volcanic event and appears to have

continued into the Quaternary as indicated by numerous normal fault scarps displacing the trachyandesites and Quaternary alluvium around the margins of the valley.

The west side of Ralston Valley is marked by a discontinuous fault system which trends northward along the margin of the valley alternately within bedrock and older alluvial fans. This system transects the Miocene Red Mountain trachyandesites between Red Mountain and Thunder Mountain and extends into the alluvium of northern Ralston Valley to the southern end of the Toquima Range.

The east side of southern Ralston Valley is characterized by a sinuous bedrock-alluvium contact typical of older or unfaulted mountain fronts. The eastern margin of northern Ralston Valley is faulted along the base of Big Ten Peak. the site of a middle Tertiary caldera. Although the faulting is along the projected margin of the caldera, its sense of displacement indicates that it is due to late Tertiary Basin and Range faulting rather than movement along or reactivation of the ancient ring-fracture system.

The most prominent surface faulting in Ralston Valley coincides with the southeastern flank of the Toquima Range and is compatible with faulting farther north which indicates that the Toquima Range is a down-to-the-west tilted fault block.

4.0 INTERPRETATION

A valley filled with alluvium which has low density relative to the surrounding bedrock creates a negative gravity anomaly. Thus, gravity profiles across such valleys are typically U-shaped, low in the middle of the valley where the fill is thickest, and high on the ends where the fill thins and bedrock emerges. The basis for the interpretation is the Complete Bouguer Anomaly (CBA). (The CBA is defined in Appendix A1.4.) Contours of the CBA gravity field in Ralston Valley are shown in Drawing 1. The contours were generated by a computer program. Since contouring and other mathematical treatment of irregularly spaced data are inefficient, the station CBA and elevation data were first reduced to sets of values at uniformly spaced points (nodes) in a geographic array, or grid. The value at a node was calculated from the station data within a circular area around the node. The algorithm which calculated the nodal value used a bell-shaped function to weight the station values. In this way, those station values nearest the node had the greatest influence on the calculated value. A node spacing of 1.0 mile (1.6 km) was chosen to match the average data spacing.

4.1 REGIONAL-RESIDUAL SEPARATION

A fundamental part of the gravity interpretation is the separation of regional effects from the local effects of the valley and its fill. The CBA contains long wavelength components from deep and broad geologic structures extending far beyond the valley. These long wavelength components, called the

regional gravity, have been approximated by upward continuation of the gravity field. Upward continuations were made to successively higher elevations until the negative anomaly over the valley was essentially smoothed out. The final continuation was calculated at an elevation of 91,000 feet (27,737 m). This regional field was subtracted from the CBA, and the resulting residual gravity anomaly was adjusted by a constant -7.5 milligals so that the zero residual approximately fits the Paleozoic rock outcrops.

4.2 DENSITY SELECTION

To construct a geologic model from the residual gravity anomaly, it is necessary to select values of density representative of the basin fill and the underlying rock. Because only generalized density information exists, the geologic interpretation of the gravity data can be only a coarse approximation.

The density selected to represent the basin fill was 2.3 g/cm^3. Available density values for the alluvium are restricted to depths less then 300 feet (91 m). These values were obtained from samples obtained during Characterization studies from eight 160-foot (49-m) deep boreholes drilled during 1977 (Fugro National, Inc., 1979). The maximum density measured was 2.17 g/cm^3. The greater value of 2.3 g/cm^3 was selected to account for compaction with depth (compaction with depth and age is discussed by Woollard, 1962) and for the probable presence of volcanic flow material intercalated with the alluvium.

In northern Ralston Valley, the trend of the CBA is to become more negative toward the Monitor Range on the eastern flank. This indicates that the volcanic rocks comprising the Monitor Range are either relatively low density or extremely thick.

The underlying basement material is thought to be predominantly Paleozoic carbonate rocks. Middle Tertiary volcanics probably lie between the alluvial basin deposits and the carbonate basement, but little is known about their thickness and density. The density of siliceous to intermediate volcanic rocks generally ranges between 2.0 to 2.5 g/cm^3 depending on the degree of welding, compaction, and alteration. The older volcanics in the Ralston area are probably at the higher end of the density range, being approximately equivalent to dense alluvium or between the density of alluvium and the density of the basement rocks. The information available regarding the volume and characteristics of subsurface volcanic rocks in Ralston Valley is insufficient to make an estimate of their effect on the gravitational field: but it is thought that for most of the valley, the residual gravity anomaly is the result of the density contrast between the Paleozoic basement and the overlying materials, alluvium, and/or volcanic materials.

Published values for carbonate rocks typically range between 2.6 and 2.9 g/cm^3. The Paleozoic carbonate rocks in Nevada and Utah are generally reported to be relatively high density, on the order of 2.8 g/cm^3. This value was selected to represent the density of the Paleozoic basement. A density contrast of

-0.50 g/cm^3 was used for the basic, two-layer modeling of the valley.

Low density material, about 2.0 g/cm^3, may also be present in Ralston Valley and may account for the closed gravity lows, 1 and 2, in Drawing 1.

4.3 MODELING

Two-layer modeling was done with the aid of a computer program which iteratively calculates a three-dimensional solution of gravity anomaly data (Cordell, 1970). The gravity anomaly is represented by discrete values on a two-dimensional grid. The source of the anomaly (the volume of low-density valley fill) is represented by a set of vertical prism elements. The tops of the prisms lie in a common horizontal plane and their bottoms collectively represent the bottom of the valley fill. Each prism has a uniform density and a cross-sectional area equal to one grid square. A grid square of 1.0 mile by 1.0 mile (1.6 km by 1.6 km) was selected as representative of the gravity station distribution. Computations were made for 12 iterations of mutually interactive prism adjustments.

The calculated thickness of the valley fill depends upon the residual anomaly and the density contrast (i.e., fill density minus rock density) used. Since neither fill nor rock density is perfectly known, nor even uniform, the calculated thickness should be expected to contain a corresponding degree of uncertainty. A source of error in modeling Ralston Valley as an

alluvium/bedrock system is the possibility of buried volcanic rocks in the valley.

4.4 DISCUSSION OF RESULTS

The interpreted shape and structure of Ralston Valley basin differs considerably from the long, steep-sided, block-faulted grabens that are typically associated with Quaternary Great Basin fault-block tectonics.

The gravity data are difficult to integrate completely into geologic interpretations consistent with these features because of two large-amplitude, negative anomalies (features 1 and 2 in Drawing 1) which indicate deep subcircular basins or depressions and the increasingly negative trend of the gravity field beneath the Monitor Range.

Drawing 2 shows the depth to bedrock contours and bedrock faults interpreted when the Ralston Valley gravity data are modeled as a basic two layer system. The general picture is a broad, shallow depression containing two extremely deep, quasi-circular features. The larger of these structures (feature 2 in Drawing 2) dominates the southern half of the basin and the smaller, but equally deep, structure (feature 1) is in the northern half of the basin.

As shown in Drawing 2, the deeper, central portions of these features have a slight N-S elongation, but the shallower contours indicate a NW-SE elongation in the northern basin and an E-W elongation in the southern basin. The NW-SE trend in

feature 1 coincides with the alluvial-filled pass between the Toquima Range and the San Antonio Mountains suggesting a crustal discontinuity between these two mountain blocks. The E-W cross-trend associated with feature 2 does not appear to correlate to any major surficial geologic structures but may coincide with a group of Miocene rhyolite intrusions. Both of the deep structures are nearer the western side of the valley indicating a subsurface pediment on the east side of the valley extending beneath the alluvium from the western edge of the Monitor Range to about the middle of the valley, where the steep gradients may indicate downfaulting to depths of about 10,000 feet (3048 m).

Even though the two-layer model results in what appears to be two structurally unrelated basins, it is possible that the two gravity anomalies represent portions of the same graben which was essentially filled by relatively dense volcanic flows between Red Mountain and Thunder Mountain. In this case, the western edge of the graben would be along the major N-S trending fault which extends from the west side of Mud Lake (Figure 2) to the southern tip of the Toquima Range, and the eastern edge would be formed by a fault extending between the two features near the center of the topographic valley.

An alternative interpretation is that the structural basin is no more than about 3000 feet (914 m) deep, and that the closed gravity anomalies are caused by low density materials, such as air-fall tuff and other volcanic debris, that have accumulated within calderas. Since this part of Nevada contains numerous

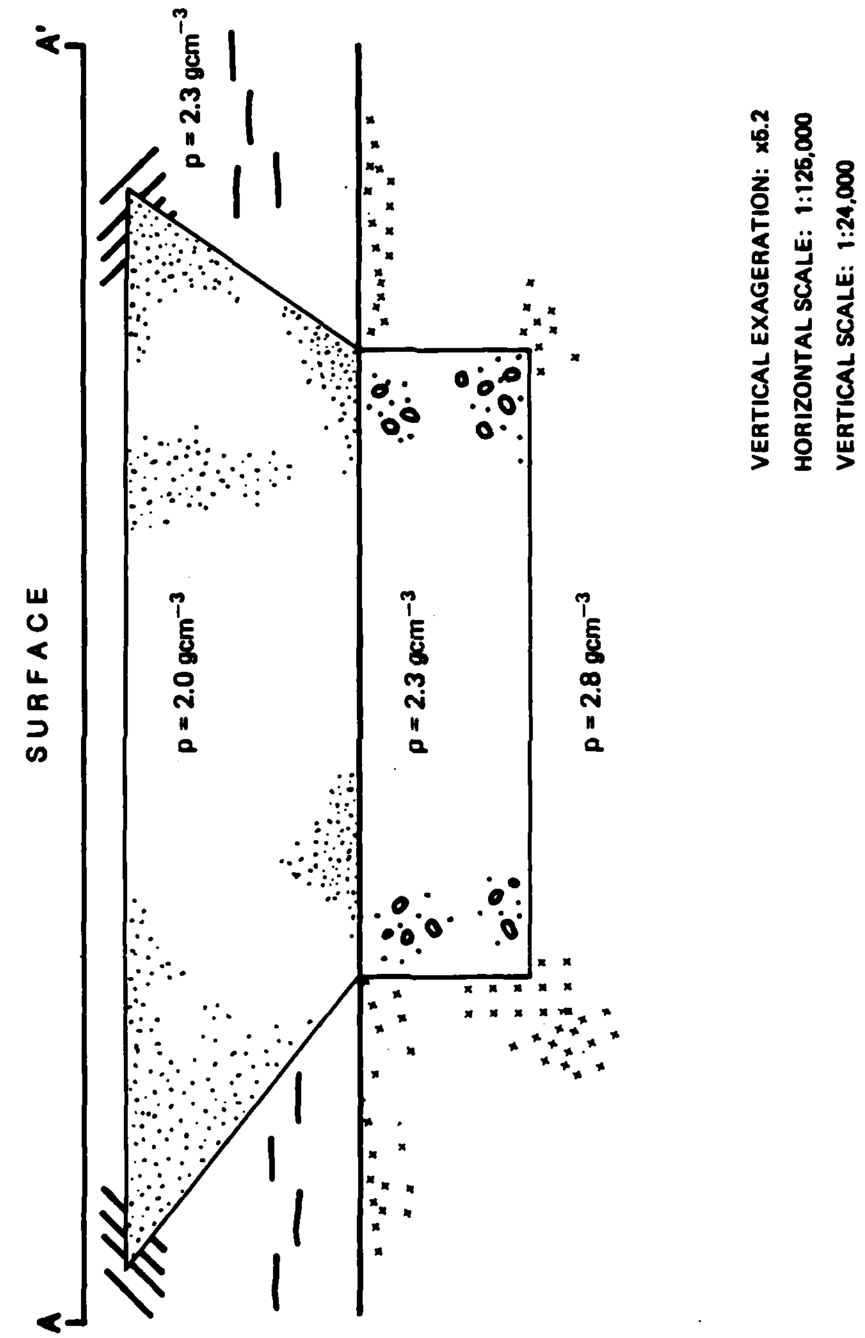
calderas in the mountains, such as Big Ten Peak, this appears to be a plausible interpretation. In the two-layer model, the trend of the depth contours toward Big Ten Peak indicates that the Paleozoic rocks are becoming deeper beneath the Monitor Range. The negative gravity values that cause this trend in the two-layer model also may be the result of low density materials accumulated in the Big Ten Peak Caldera. If this is the case, the Paleozoic rocks in the Monitor Range may be much shallower than indicated in Drawing 2.

The alternative interpretation was tested quantitatively to see if models of reasonable dimensions (size and density) could satisfy the anomalies. To illustrate that they can, a cross-section view of a simple caldera model which satisfies residual gravity anomaly 2 (Drawing 1) is shown in Figure 3. The model contains two layers having characteristics that follow.

- Layer 1 extends from 500 feet (152 m) below land surface to a depth of 3000 feet (914 m) and has a mean density of 2.0 g/cm^3. This low density is meant to represent a mixture of air-fall tuff and other low density volcanic debris. The gradual slope of the Bouguer residual anomaly indicates that the sides of this layer have slopes varying from about 12° to less than 8°.

- Layer 2, assigned a mean density of 2.3 g/cm^3, extends from 3000 feet (914 m) below the land surface to a depth of 5000 feet (1524 m). This layer is meant to represent more dense and well-consolidated volcanic debris. It is not possible, using the form of the Bouguer residual anomaly, to tell how steep the sides of this layer are.

Plan views of both layers of the caldera model are shown in Figure 4. There could be many other geologically reasonable caldera models which would satisfy this gravity anomaly, but with



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CROSS-SECTION VIEW
CALDERA MODEL

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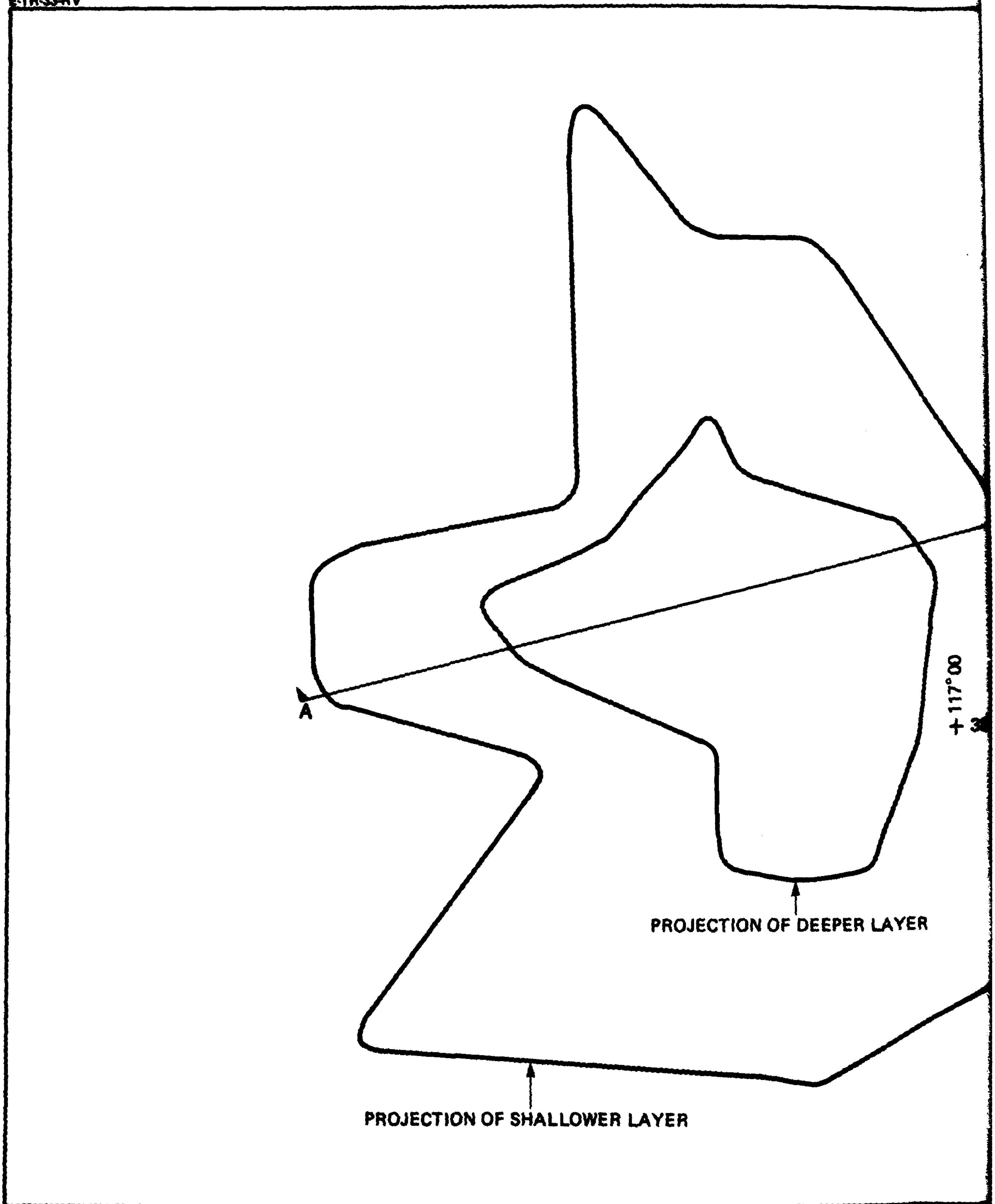
FIGURE 3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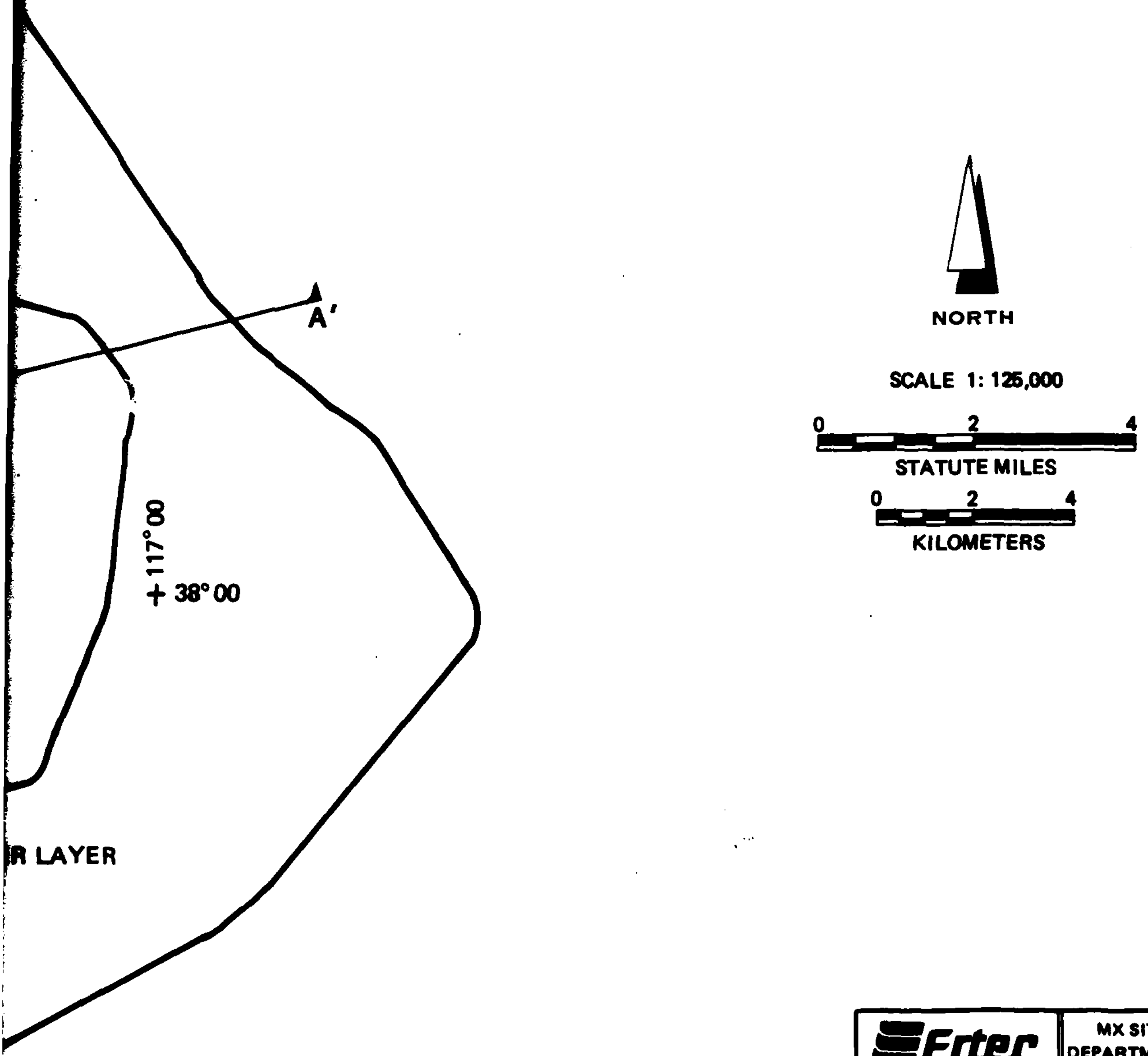

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PLAN VIEW, CALDERA MODEL
FEATURE 2

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FIGURE 4

so little subsurface data, there is no basis for selecting a preferred model. However, this model serves to illustrate that buried calderas are viable explanations of gravity anomalies such as features 1 and 2 in Drawing 1.

Two seismic refraction lines (Fugro National, Inc., 1979) in the Thunder Mountain area tend to support the gravity interpretation in that they indicate a thin accumulation of low velocity material (<8500 feet/sec [2591 m/sec]) which is probably nonindurated to indurated alluvial sands and gravels. This material is underlain by several layers of higher velocity material (>10,500 feet/sec [3048 m/sec]) which may represent Tertiary volcanic rock and/or Paleozoic sedimentary formations. These lines are too short to yield regional information, but they do indicate that alluvium is thin (<1000 feet [305 m] thick) in the pass between Thunder Mountain and the Midway Hills.

5.0 CONCLUSIONS

The gravity data collected in the Ralston Valley area do not yield a unique interpretation. Whereas the surficial geologic data suggest tilt-block or horst-graben structures, the gravity data do not support a simple elongate, down-faulted graben beneath Ralston Valley. Three interpretations appear plausible:

1. Partial infilling of an ancestral deep graben by late Tertiary volcanics;
2. Two separate, small, deep grabens, one below northern Ralston Valley and one below southern Ralston Valley; and
3. Low density sedimentary and volcanic accumulations associated with caldera structures in a shallow graben.

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A1.0
GENERAL PRINCIPLES OF THE GRAVITY EXPLORATION METHOD

A1.0 GENERAL PRINCIPLES OF THE GRAVITY EXPLORATION METHOD

A1.1 GENERAL

A gravity survey involves measurement of differences in the gravitational field between various points on the earth's surface. The gravitational field values being measured are the same as those influencing all objects on the surface of the earth. They are generally associated with the force which causes a 1-gm mass to be accelerated at 980 cm/sec^2. This force is normally referred to as a 1-g force.

Even though in many applications the gravitational field at the earth's surface is assumed to be constant, small but distinguishable differences in gravity occur from point to point. In a gravity survey, the variations are measured in terms of milligals. A milligal is equal to 0.001 cm/second^2 or 0.00000102 g. The differences in gravity are caused by geometrical effects, such as differences in elevation and latitude, and by lateral variations in density within the earth. The lateral density variations are a result of changes in geologic conditions. For measurements at the surface of the earth, the largest factor influencing the pull of gravity is the density of all materials between the center of the earth and the point of measurement.

To detect changes produced by differing geological conditions, it is necessary to detect differences in the gravitational field as small as a few milligals. To recognize changes due to

geological conditions, the measurements are "corrected" to account for changes due to differences in elevation and latitude.

Given this background, the basic concept of the gravitational exploration method, the anomaly, can be introduced. If, instead of being an oblate spheroid characterized by complex density variations, the earth were made up of concentric, homogeneous shells, the gravitational field would be the same at all points on the surface of the earth. The complexities in the earth's shape and material distribution are the reason that the pull of gravity is not the same from place to place. A difference in gravity between two points which is not caused by the effects of known geometrical differences, such as in elevation, latitude, and surrounding terrain, is referred to as an "anomaly."

An anomaly reflects lateral differences in material densities. The gravitational attraction is smaller at a place underlain by relatively low density material than it is at a place underlain by a relatively high density material. The term "negative gravity anomaly" describes a situation in which the pull of gravity within a prescribed area is small compared to the area surrounding it. Low density alluvial deposits in basins such as those in the Nevada-Utah region produce negative gravity anomalies in relation to the gravity values in the surrounding mountains which are formed by more dense rocks.

The objective of gravity exploration is to deduce the variations in geologic conditions that produce the gravity anomalies identified during a gravity survey.

A1.2 INSTRUMENTS

The sensing element of a LaCoste and Romberg gravimeter is a mass suspended by a zero-length spring. Deflections of the mass from a null position are proportional to changes in gravitational attraction. These instruments are sealed and compensated for atmospheric pressure changes. They are maintained at a constant temperature by an internal heater element and thermostat. A gravimeter does not measure the absolute value of gravity directly. It measures relative values of gravity between one point and the next. Gravitational differences as small as 0.01 milligal can be measured.

A1.3 FIELD PROCEDURES

The gravimeter readings were calibrated in terms of absolute gravity by taking readings twice daily at nearby USGS gravity base stations. Gravimeter readings fluctuate because of small time-related deviations due to the effect of earth tides and instrument drift. Field readings were corrected to account for these deviations. The magnitude of the tidal correction was calculated using an equation suggested by Goguel (1954):

$$C = P + N\cos\phi\,(\cos\phi + \sin\phi) + S\cos\phi\,(\cos\phi - \sin\phi)$$

where C is the tidal correction factor, P, N, and S are time-related variables, and ϕ is the latitude of the observation point. Tables giving the values of P, N, and S are published annually by the European Association of Exploration Geophysicists.

The meter drift correction was based on readings taken at a designated base station at the start and end of each day. Any difference between these two readings after they were corrected for tidal effects was considered to have been the result of instrumental drift. It was assumed that this drift occurred at a uniform rate between the two readings. Corrections for drift were typically only a few hundredths of a milligal. Readings corrected for tidal effects and instrumental drift represented the observed gravity at each station. The observed gravity values represent the total gravitational pull of the entire earth at the measurement stations.

A1.4 DATA REDUCTION

Several corrections or reductions are made to the observed gravity to isolate the portion of the gravitational pull which is due to the crustal and near-surface materials. The gravity remaining after these reductions is called the "Bouguer Anomaly." Bouguer Anomaly values are the basis for geologic interpretation. To obtain the Bouguer Anomaly, the observed gravity is adjusted to the value it would have had if it had been measured at the geoid, a theoretically defined surface which approximates the surface of mean sea level. The difference between the "adjusted" observed gravity and the gravity at the geoid calculated for a theoretically homogeneous earth is the Bouguer Anomaly.

Four separate reductions, to account for four geometrical effects, are made to the observed gravity at each station to arrive at its Bouguer Anomaly value.

a. <u>Free-Air Effect</u>: Gravitational attraction varies inversely as the square of the distance from the center of the earth. Thus corrections must be applied for elevation. Observed gravity levels are corrected for elevation using the normal vertical gradient of:

$$FA = -0.09406 \text{ mg/ft } (-0.3086 \text{ milligals/meter})$$

where FA is the free-air effect (the rate of change of gravity with distance from the center of the earth). The free-air correction is positive in sign since the correction is opposite the effect.

b. <u>Bouguer Effect</u>: Like the free-air effect, the Bouguer effect is a function of the elevation of the station, but it considers the influence of a slab of earth materials between the observation point on the surface of the earth and the corresponding point on the geoid (sea level). Normal practice, which is to assume that the density of the slab is 2.67 grams per cubic centimeter, was followed in these studies. The Bouguer correction (B_c), which is opposite in sign to the free-air correction, was defined according to the following formula.

$$B_c = 0.01276\ (2.67)\ h_f \text{ (milligals per foot)}$$

$$B_c = 0.04185\ (2.67)\ h_m \text{ (milligals per meter)}$$

where h_f is the height above sea level in feet and h_m is the height in meters.

c. <u>Latitude Effect</u>: Points at different latitudes will have different "gravities" for two reasons. The earth (and the geoid) is spheroidal, or flattened at the poles. Since points at higher latitudes are closer to the center of the earth than points near the equator, the gravity at the higher latitudes is larger. As the earth spins, the centrifugal acceleration causes a slight decrease in the measured gravity. At the higher latitudes where the earth's circles of latitude are smaller, the centrifugal acceleration diminishes. The gravity formula for the Geodetic Reference System, 1967, gives the theoretical value of gravity at the geoid as a function of latitude. It is:

$$g = 978.0381\ (1 + 0.0053204 \sin^2 \phi - 0.0000058 \sin^2 2\phi) \text{ gals}$$

where g is the theoretical acceleration of gravity and ϕ is the latitude in degrees. The positive term accounts for the spheroidal shape of the earth. The negative term adjusts for the centrifugal acceleration.

The previous two corrections (free air and Bouguer) have adjusted the observed gravity to the value it would have had at the geoid (sea level). The theoretical value at the geoid for the latitude of the station is then subtracted from the adjusted observed gravity. The remainder is called the Simple Bouguer Anomaly (SBA). Most of this gravity represents the effect of material beneath the station, but part of it may be due to irregularities in terrain (upper part of the Bouguer slab) away from the station.

d. <u>Terrain Effect</u>: Topographic relief around the station has a negative effect on the gravitational force at the station. A nearby hill has upward gravitational pull and a nearby valley contributes less downward attraction than a nearby material would have. Therefore, the corrections are always positive. Corrections are made to the SBA when the terrain effects were 0.1 milligal or larger. Terrain corrected Bouguer values are called the Complete Bouguer Anomaly (CBA). When the CBA is obtained, the reduction of gravity at individual measurement points (stations) is complete.

A1.5 INTERPRETATION

To interpret the gravity data, the portion of the CBA that might be caused by the light-weight, basin-fill material must be separated from that caused by the heavier bedrock material which forms the surrounding mountains and presumably the basin floor. The first step is to create a regional field. A regional field is an estimation of the values the CBA would have had if the light-weight sediments (the anomaly) had not been there. Since the valley-fill sediments are absent at the stations read in the mountains, one approach is to use the CBA values at bedrock stations as the basis for constructing a second order polynomial surface to represent a regional field over the valley.

Where there are insufficient bedrock stations to define a satisfactory regional trend, another approach is to estimate the regional by the process of upward continuation of the CBA field.

In Potential Theory, a field normal to a surface, regardless of its actual source, may be considered as originating in an areal distribution of mass on that surface, and if the field strength is known the surface density of mass (grams per square centimeter) can be calculated. The observed gravity field at the surface of the earth approximately fulfills the requirements of this theory: thus the observed (Bouguer anomaly) field can be used to compute a surficial distribution of mass which would reproduce the field, and most importantly, account for the gravity field anywhere above the surface of observation. On this basis, the Bouguer anomaly field is readily "continued" to level surfaces above the ground.

An important property of such "upward continuation" is that the resultant field (which can be represented by a contour map), with increasing altitudes of continuation, changes more with respect to shallow sources than it does with respect to deeper sources. The anomalous parts of the field ascribed to shallow density distributions tend to vanish as the continuation is carried upward whereas the field produced by deeper sources changes only slightly, so that upward continuations produce "regional"-type fields.

The difference between the CBA and the regional field is called the "residual" field or residual anomaly. The residual field is the interpreter's estimation of the gravitational effect of the geologic anomaly. The zero value of the residual anomaly is not exactly at the rock outcrop line but at some distance on the

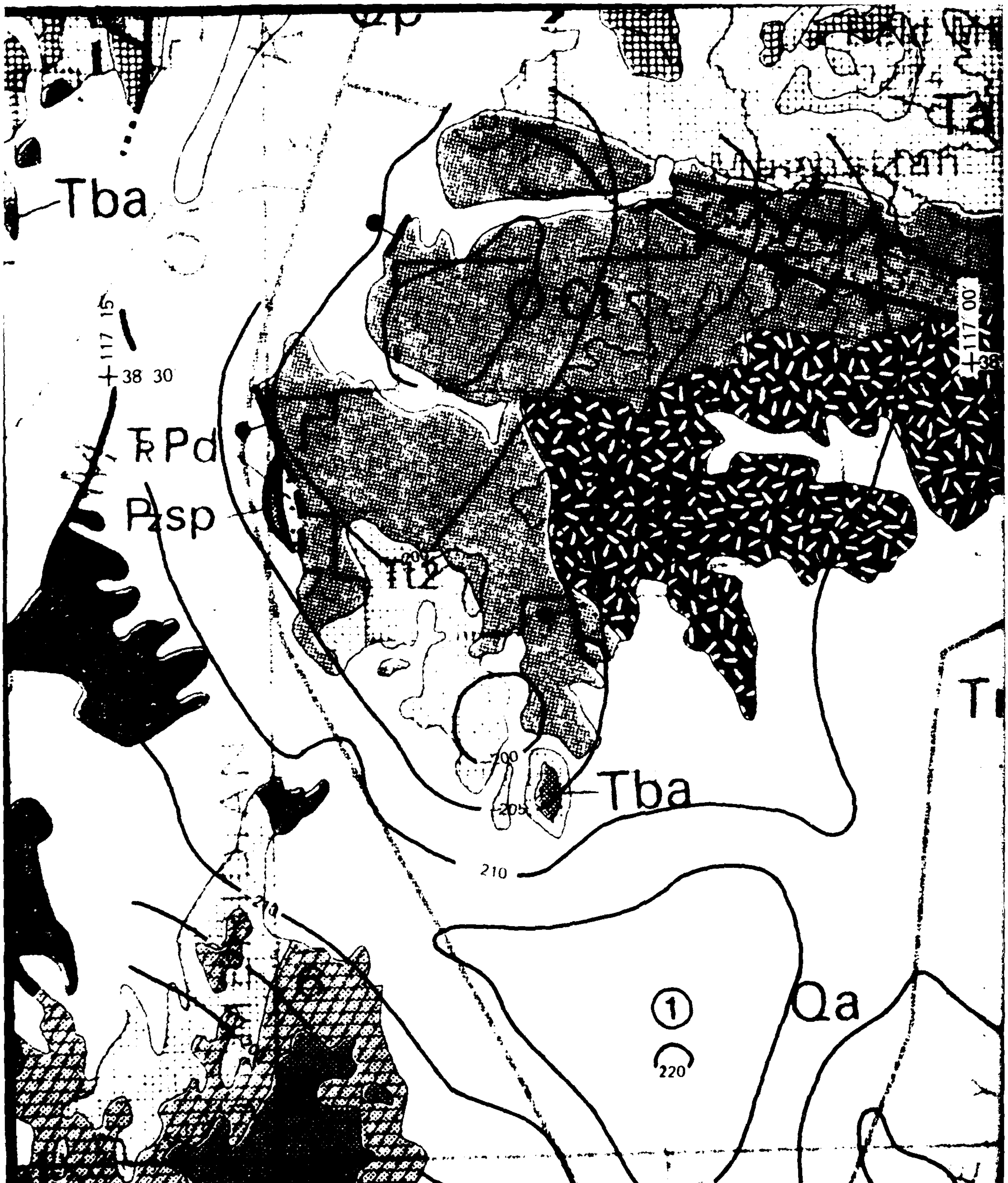
"rock" side of the contact. The reason for this is found in the explanation of the terrain effect. There is a component of gravitational attraction from material which is not directly beneath a point.

If the "regional" is well chosen, the magnitude of the residual anomaly is a function of the thickness of the anomalous (fill) material and the density contrast. The density contrast is the difference in density between the alluvial and bedrock material. If this contrast were known, an accurate calculation of the thickness could be made. In most cases, the densities are not well known and they also vary within the study area. In these cases, it is necessary to use typical densities for materials similar to those in the study area.

If the selected average density contrast is smaller than the actual density contrast, the computed depth to bedrock will be greater than the actual depth and vice-versa. The computed depth is inversely proportional to the density contrast. A ten percent error in density contrast produces a ten percent error in computed depth. An iterative computer program is used to calculate a subsurface model which will yield a gravitational field to match (approximately) the residual gravity anomaly.

The second vertical derivative (SVD) of the gravitational field is used to aid the interpreter in evaluating the subsurface mass distribution. Once the CBA field has been projected onto a uniform grid system, its SVD at the grid nodes is readily computed.

In accordance with Laplace's Equation in Free Space, the negative of the second vertical derivative is equal to the sums of the second derivatives in the x-direction and in the y-direction. The second vertical derivative is an indication of the curvature of the Bouguer anomaly field. In particular the zero-value of the SVD indicates the inflection in the field as it changes from "concave-upward" (algebraically negative SVD) to "convex-upward" (algebraically positive SVD). In a general way the zero SVD falls on the tightest contours of the field. Where contours are nearly parallel, its location can be established by eye, but where contours diverge, converge, or change direction this is not always so readily done. The zero SVD contour line may be an indicator of a line of faulting, the pinchout of a stratum, truncation of a stratum at an unconformity or merely a marked change in shape or in density of a geologic unit.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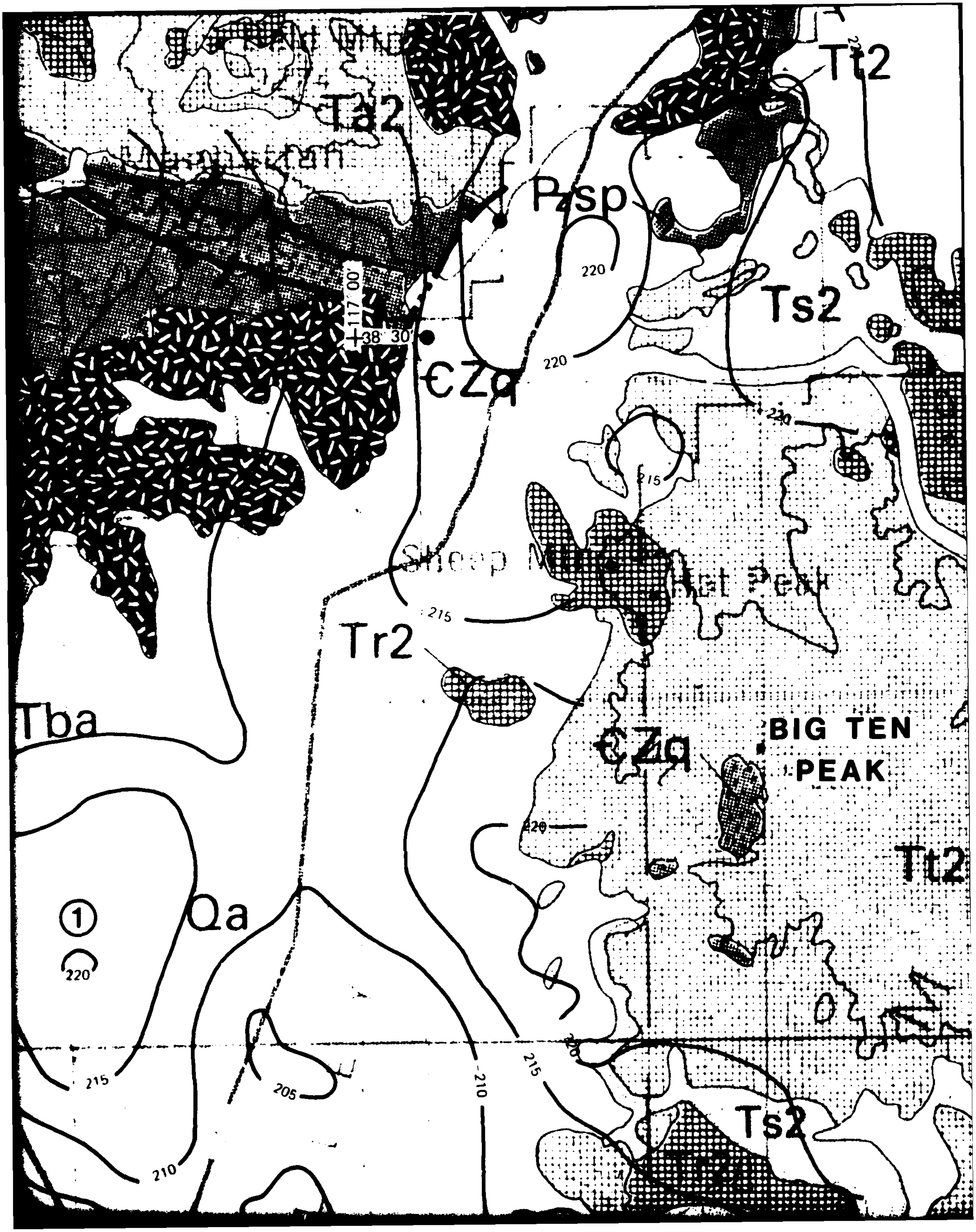

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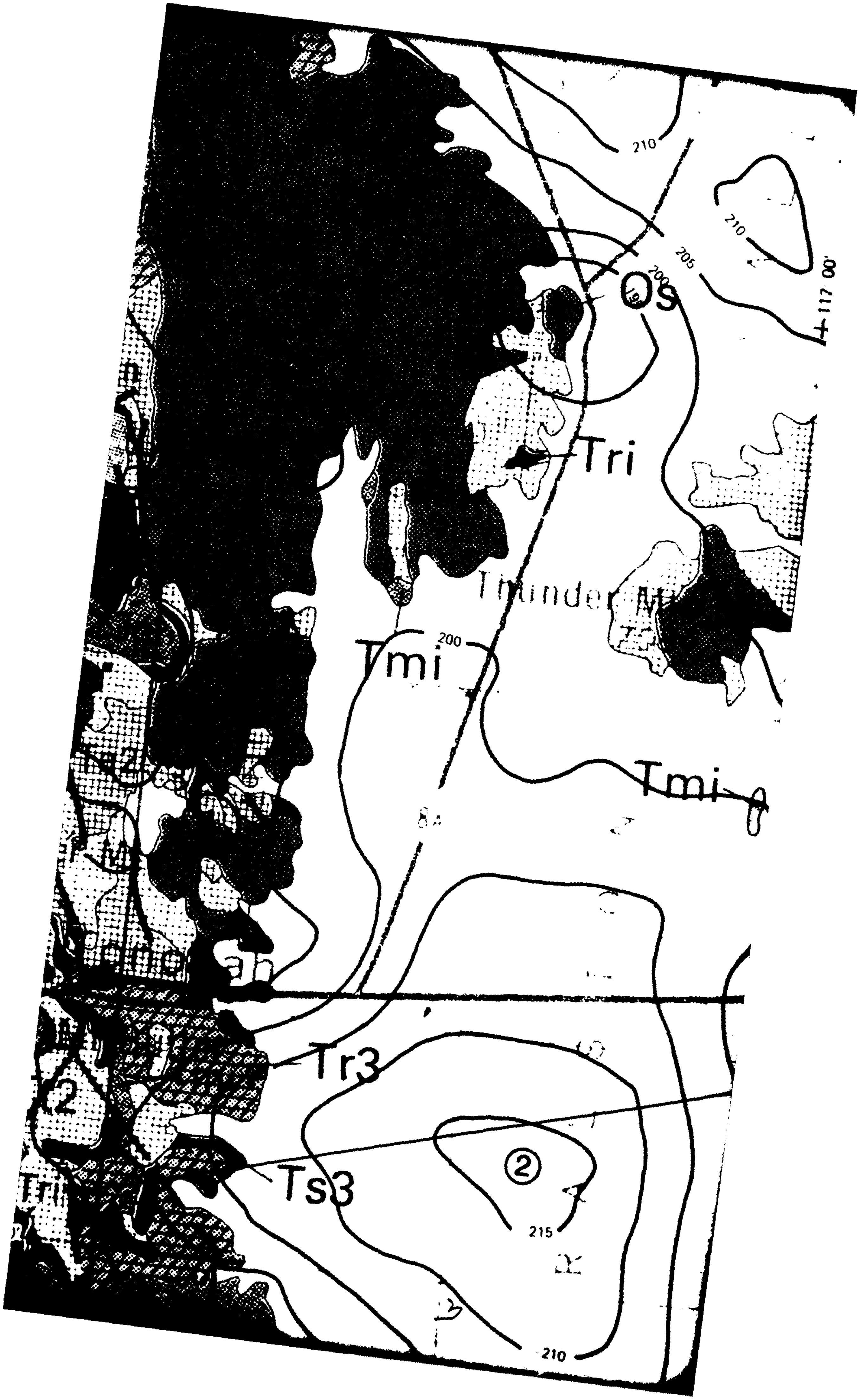
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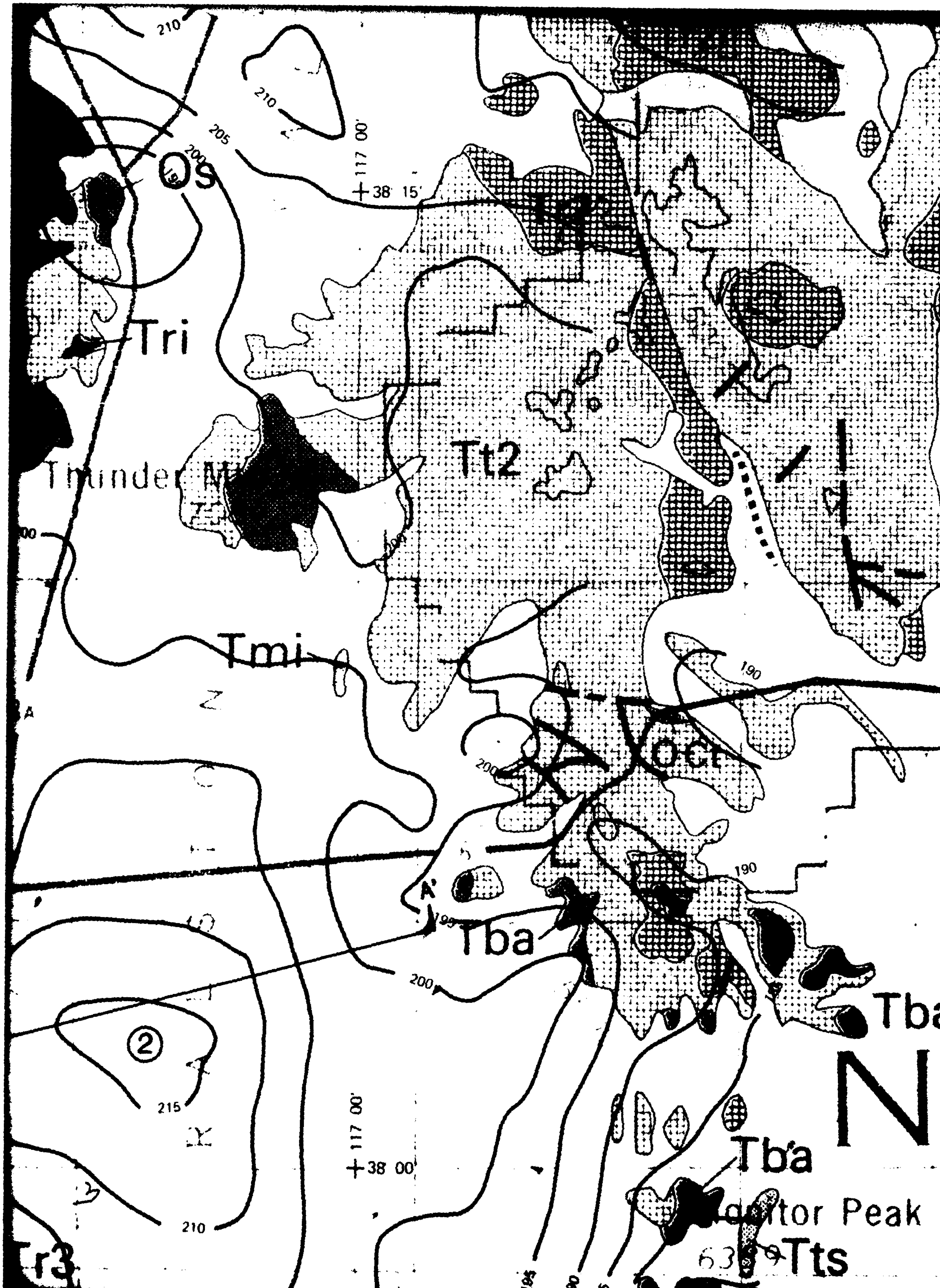

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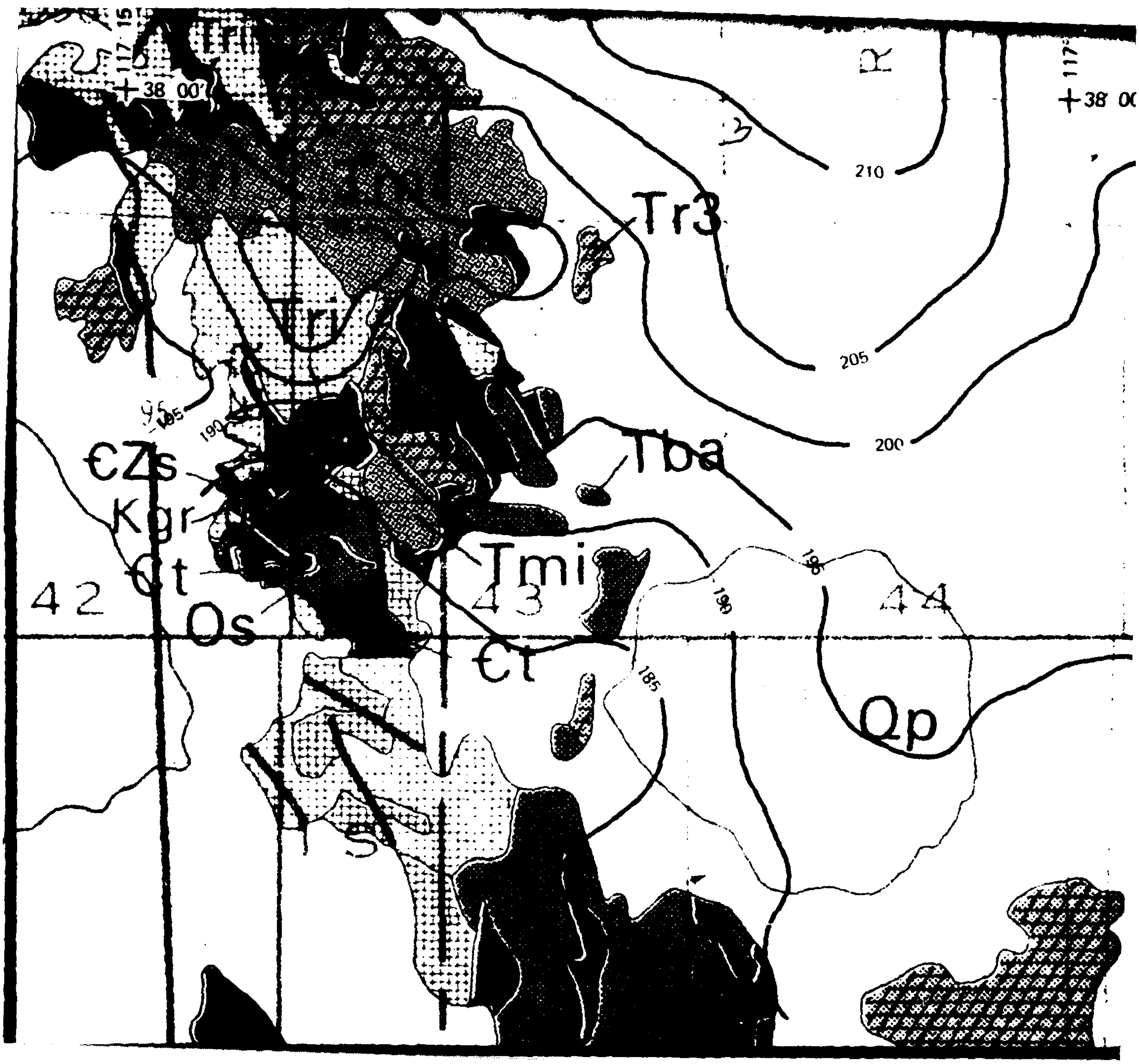

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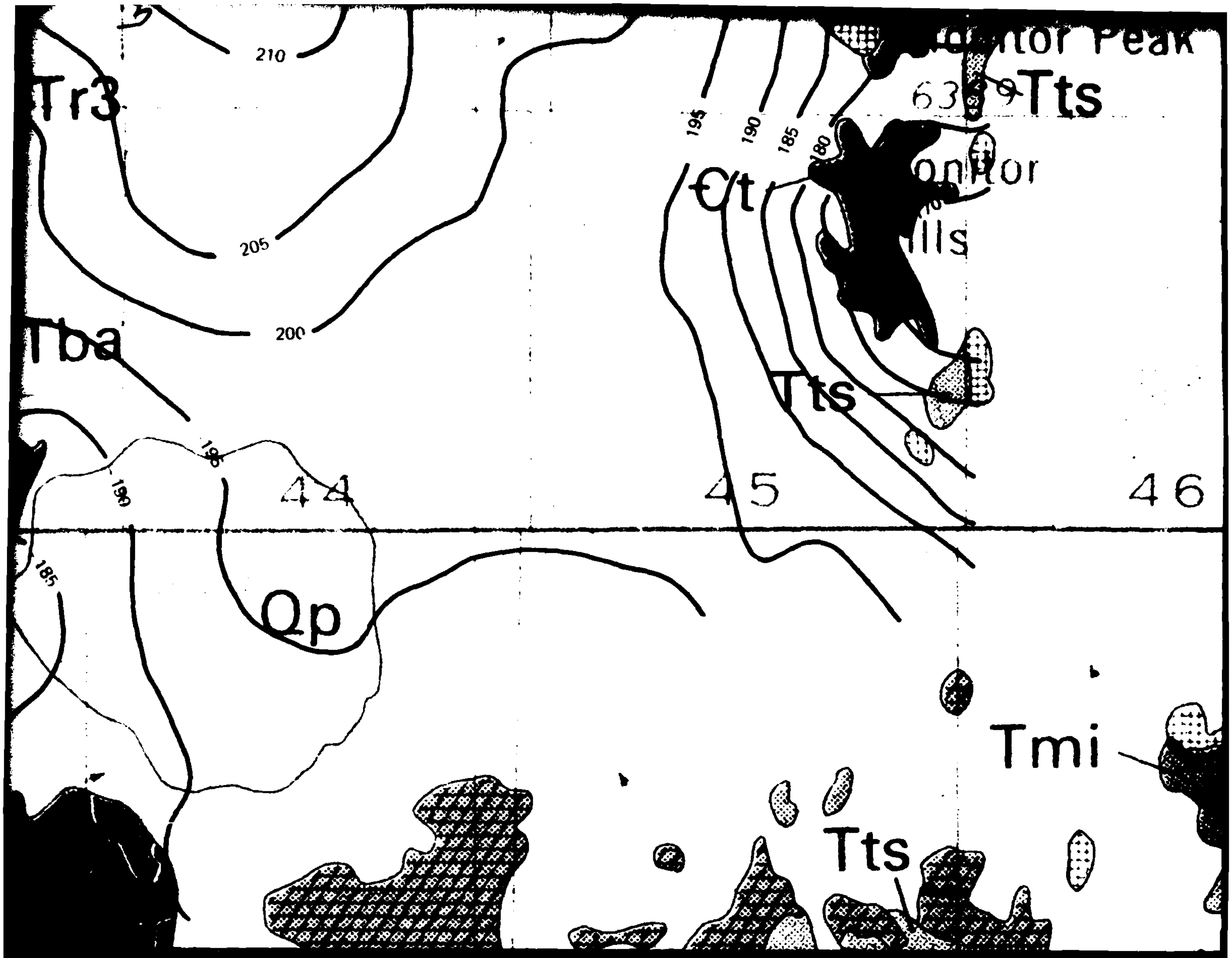

SE MAP

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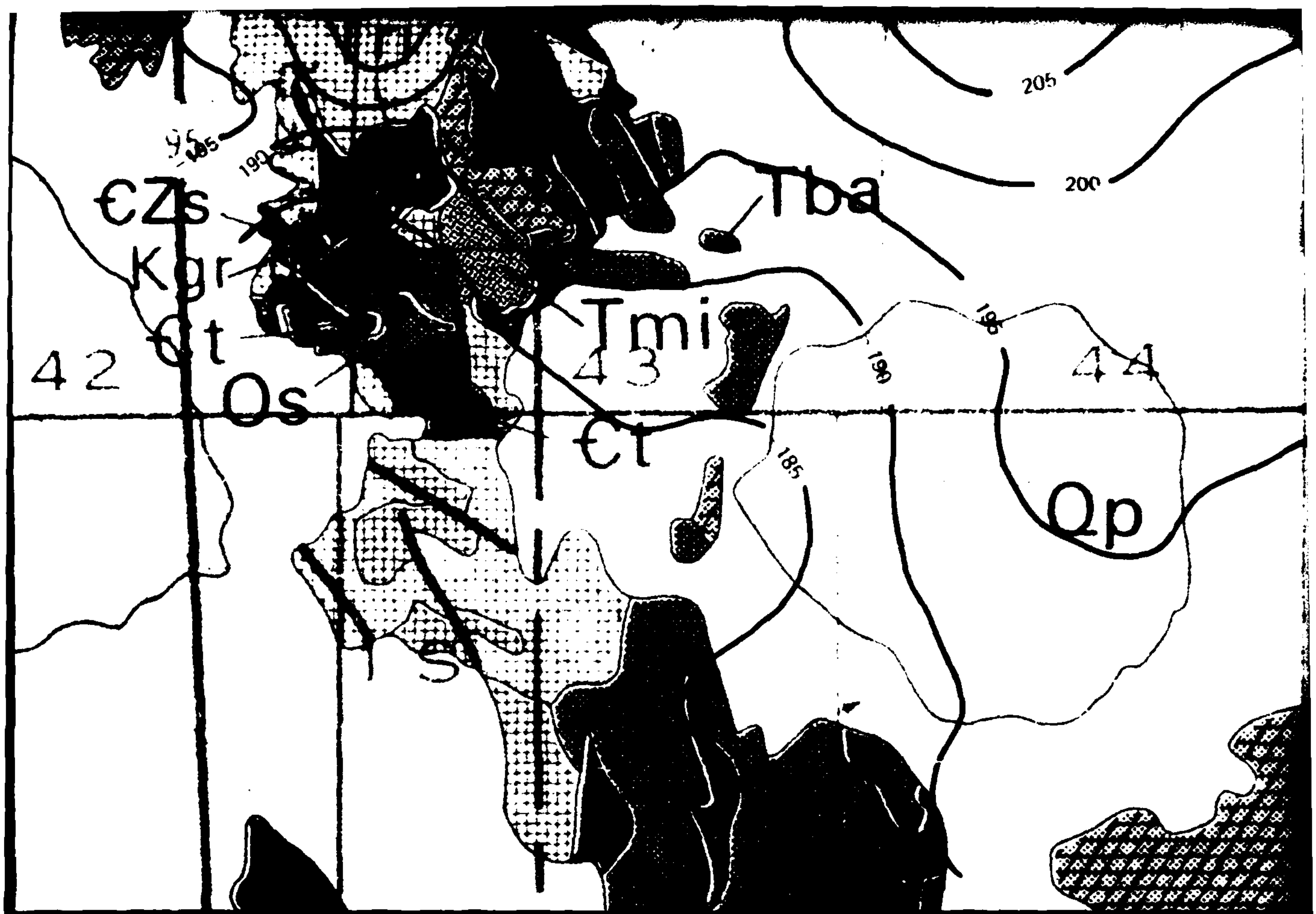
BMO/AFRCE-MX

COMPLETE BOUGUER



EXPLANATION

FAULTS SHOWN ON GEOLOGIC BASE MAP

ALLUVIAL MATERIAL

ROCK (ALL PATTERNS)

CONTOUR INTERVAL = 5 MILLIGALS

(1) GRAVITY "LOW"

A ——— A' LINE OF SECTION (FIGURE 3)

GEOLOGIC BASE MAP: STEWART & CARLSON (1978)

NORTH

SCALE 1:

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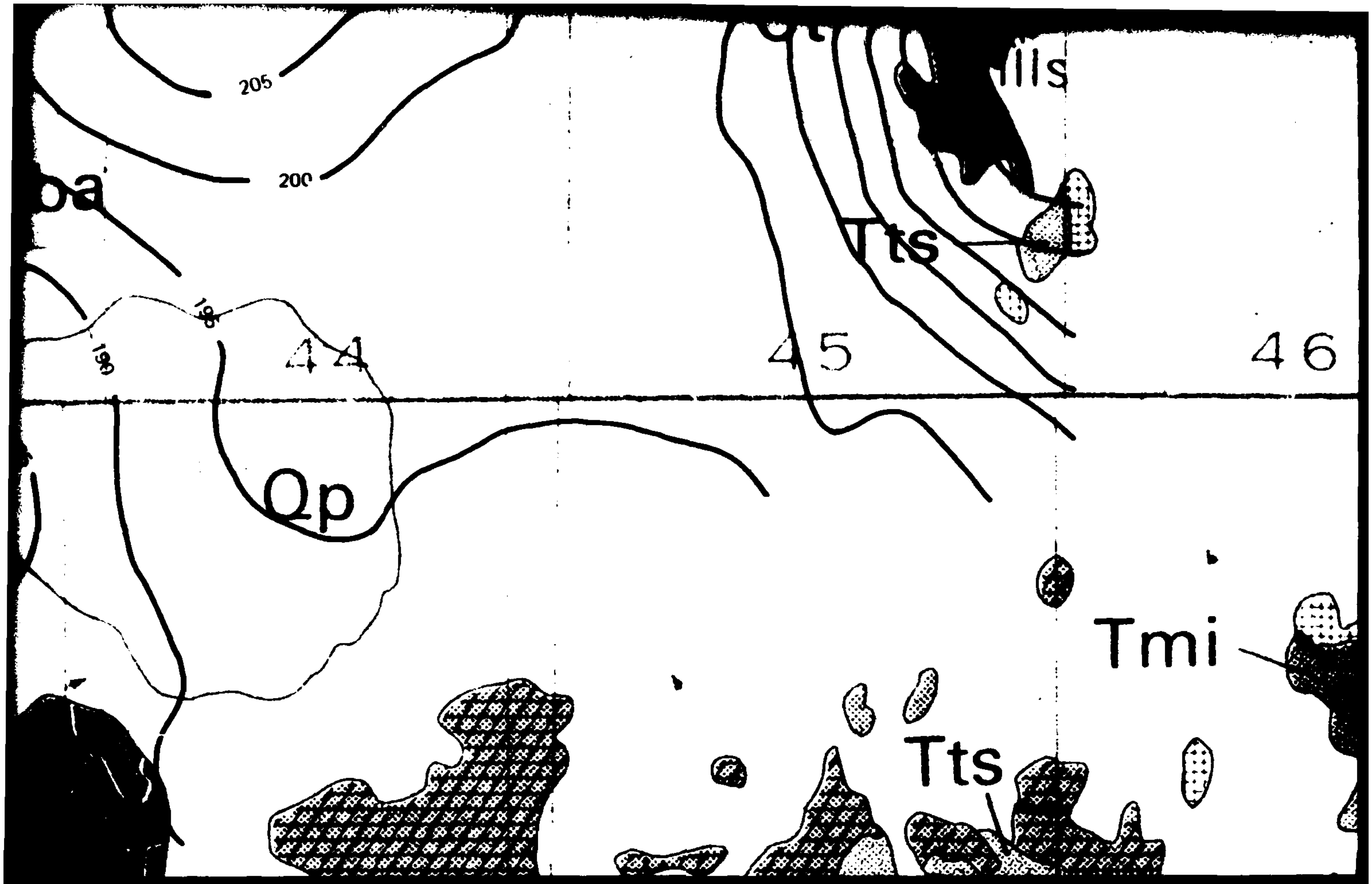
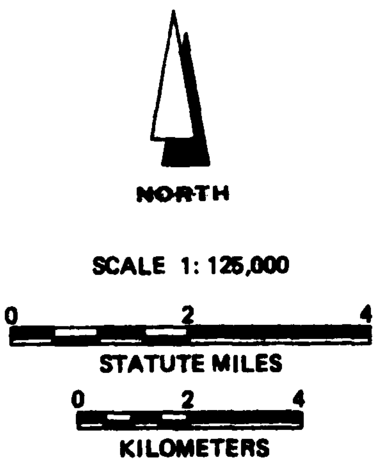


MAP



ARLSON (1978)

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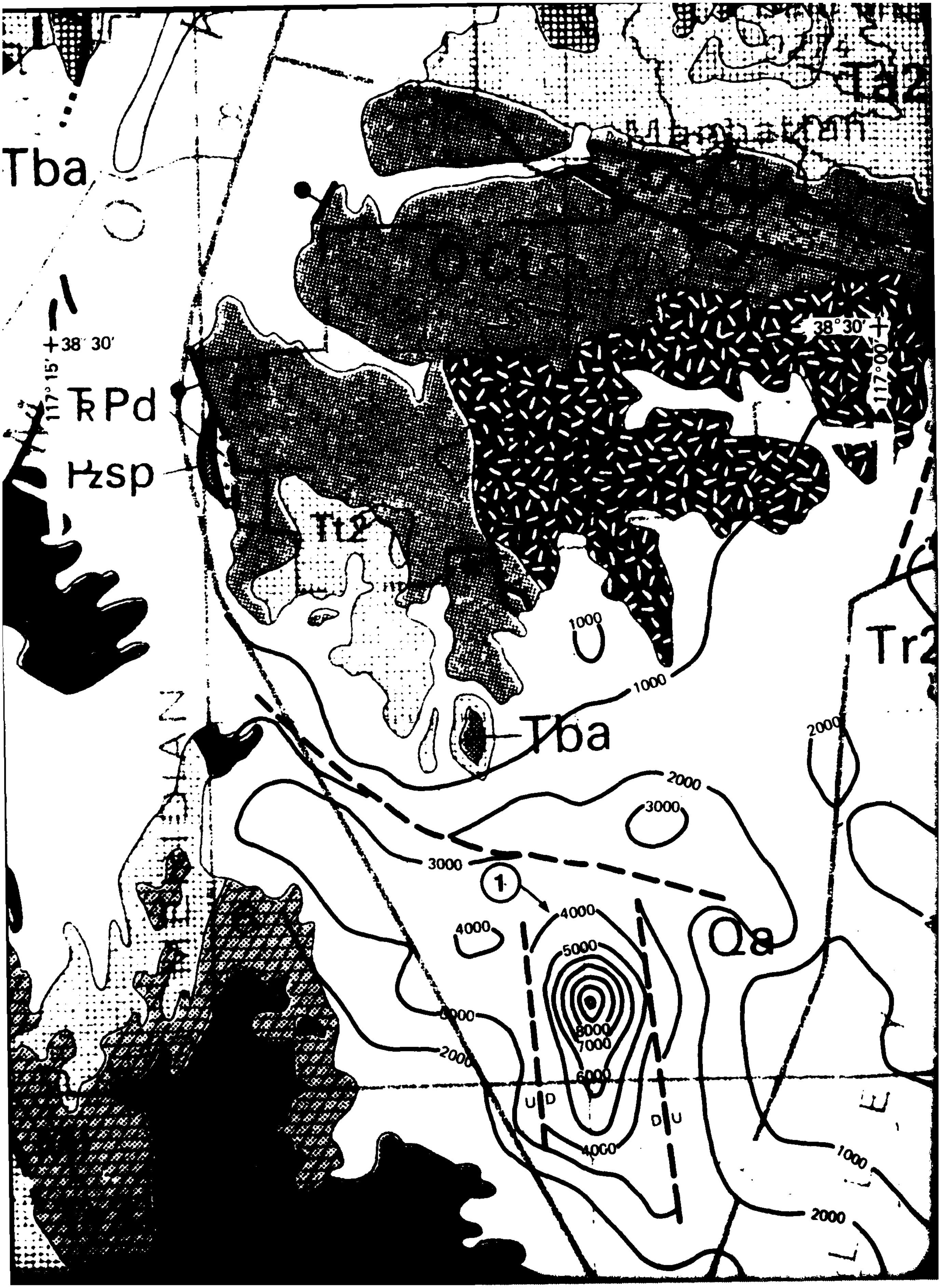
COMPLETE BOUGUER ANOMALY CONTOURS RALSTON VALLEY, NEVADA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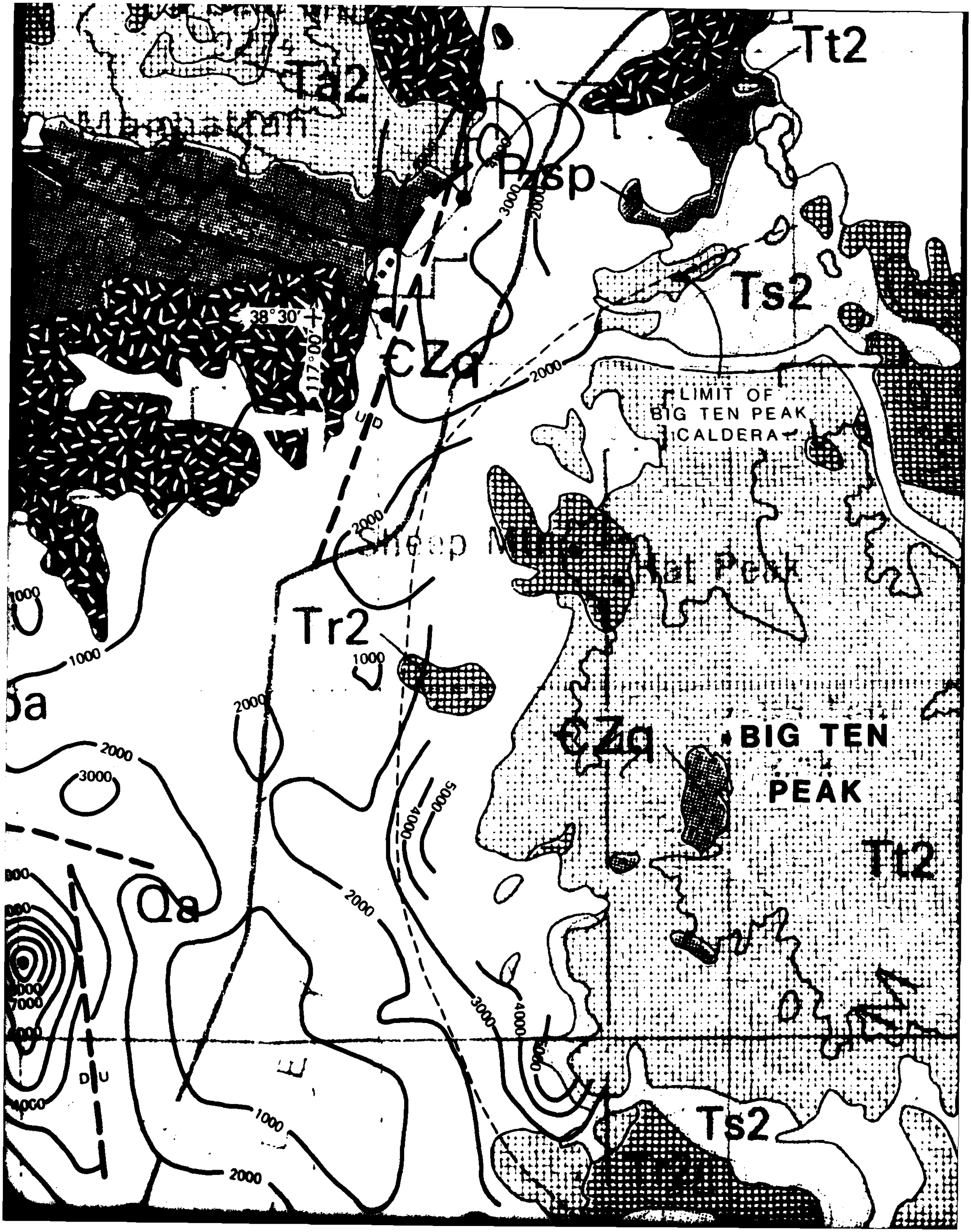
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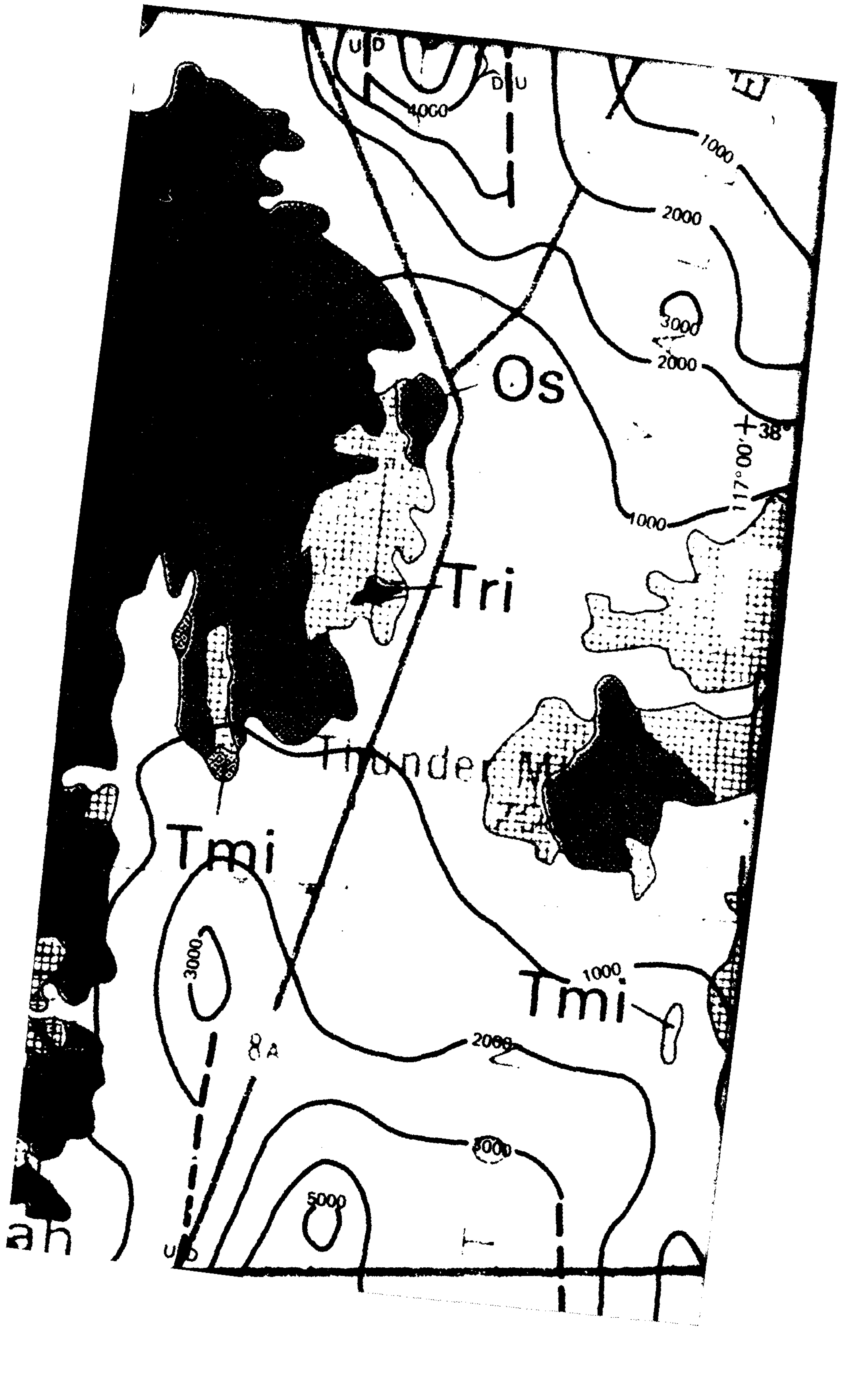

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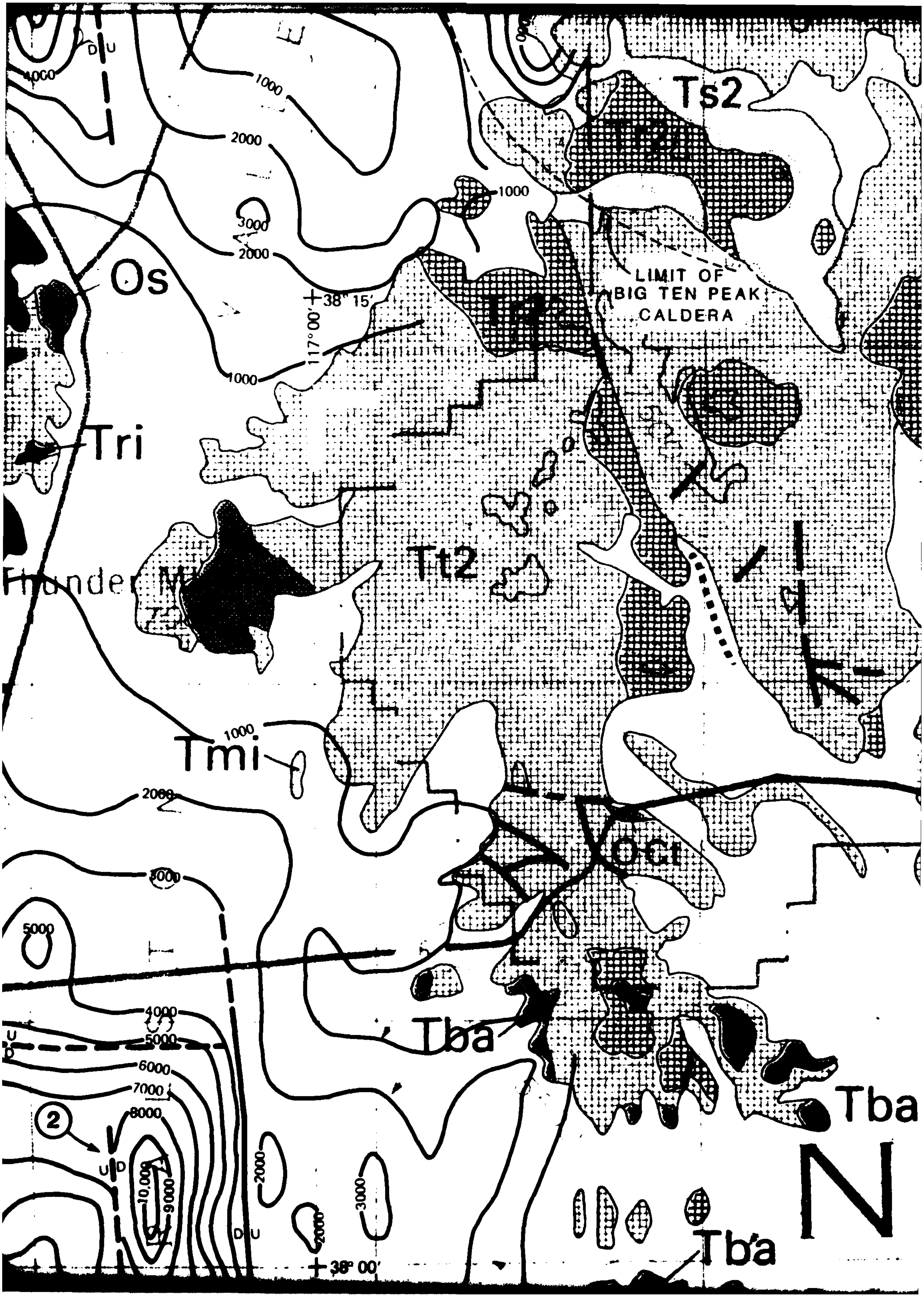

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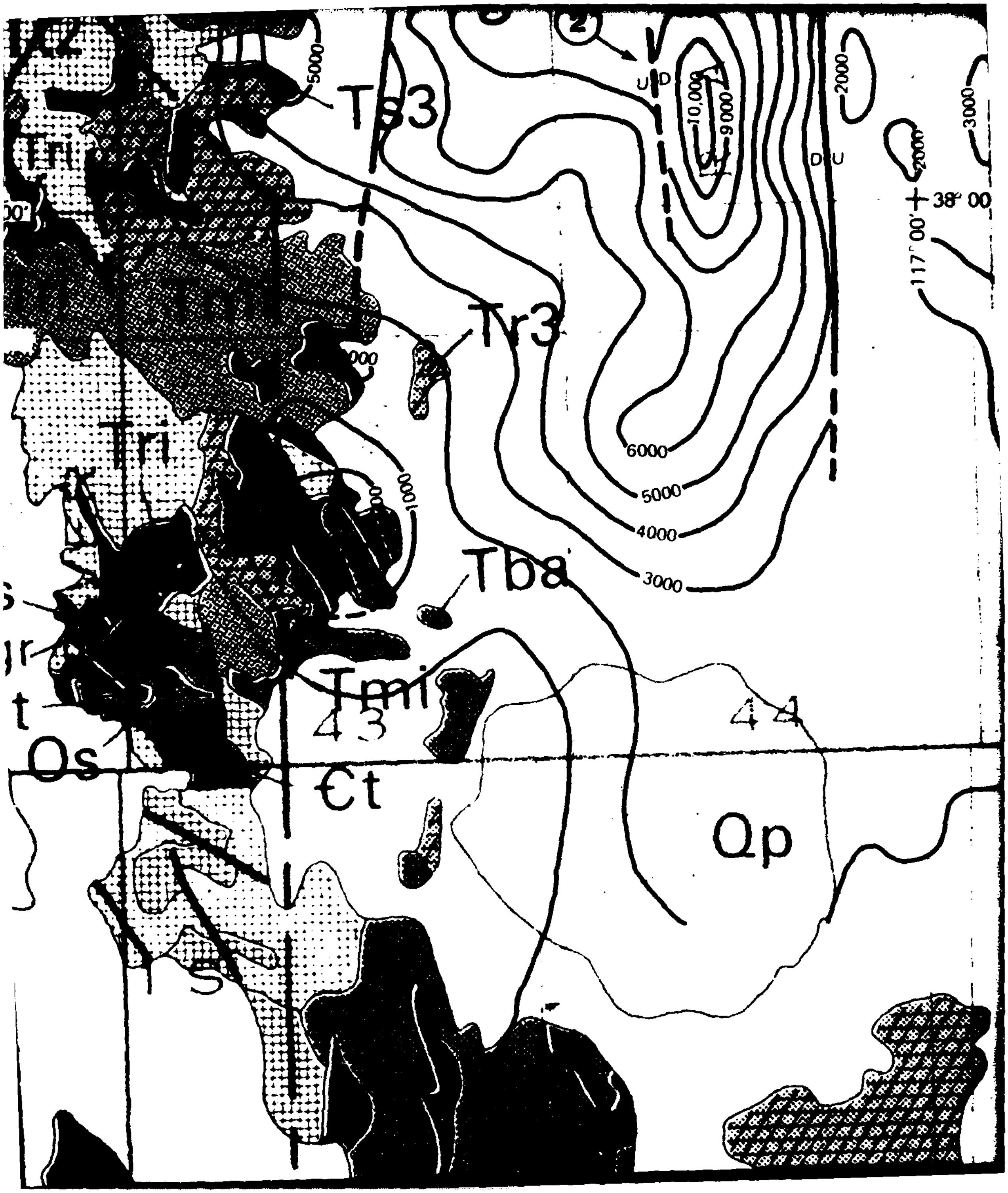
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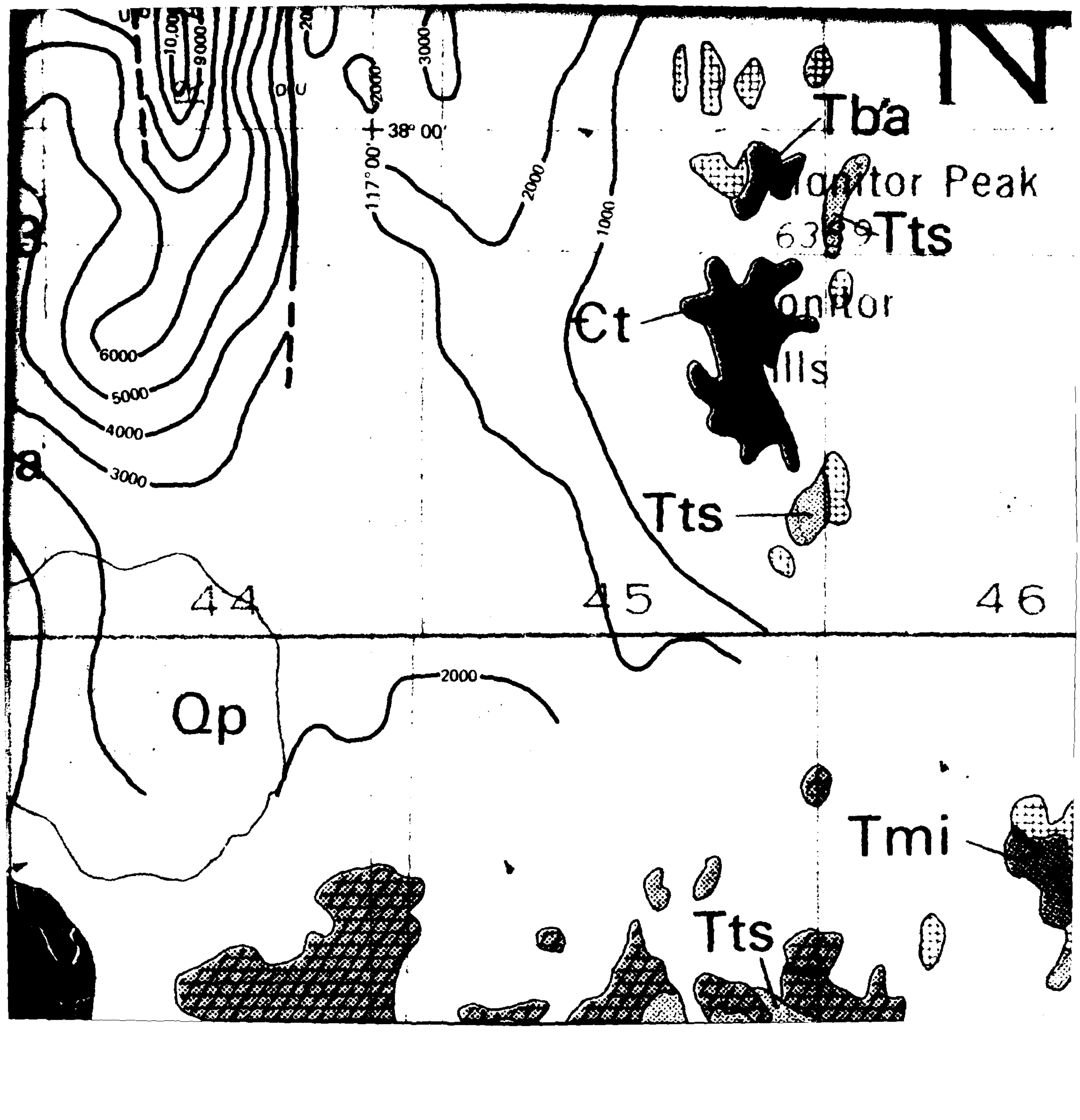

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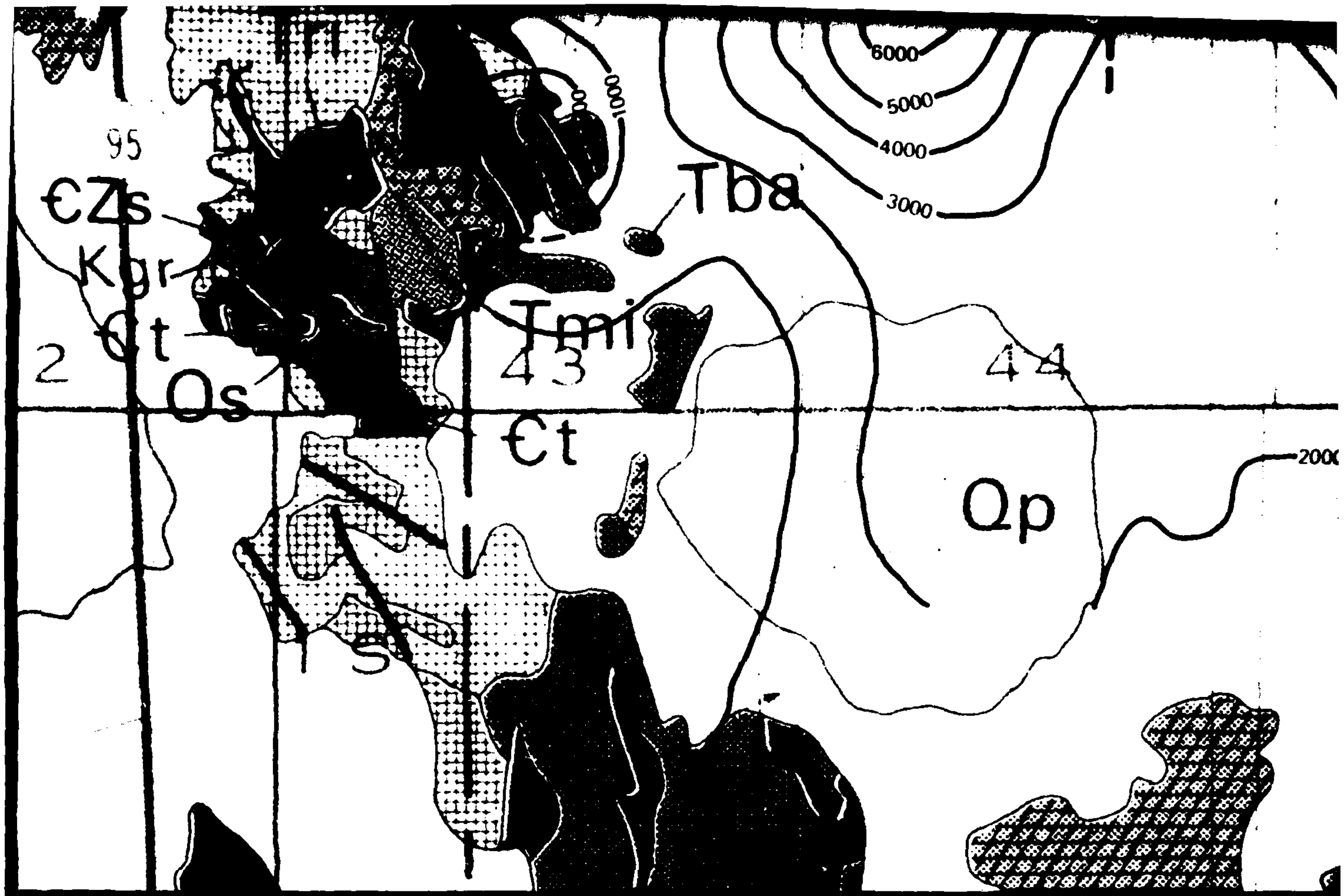

EXPLANATION

U D GRAVITY-INFERRED FAULT LOCATIONS

FAULTS SHOWN ON GEOLOGIC BASE MAP

ALLUVIAL MATERIAL

ROCK (ALL PATTERNS)

5

CONTOUR INTERVAL = 1000 FT.

(1) ANOMALOUS STRUCTURAL FEATURES

DEPTH CALCULATIONS BASED ON
DENSITY CONTRAST OF -0.5g cm3

GEOLOGIC BASE MAP: STEWART & CARLSON(1978)

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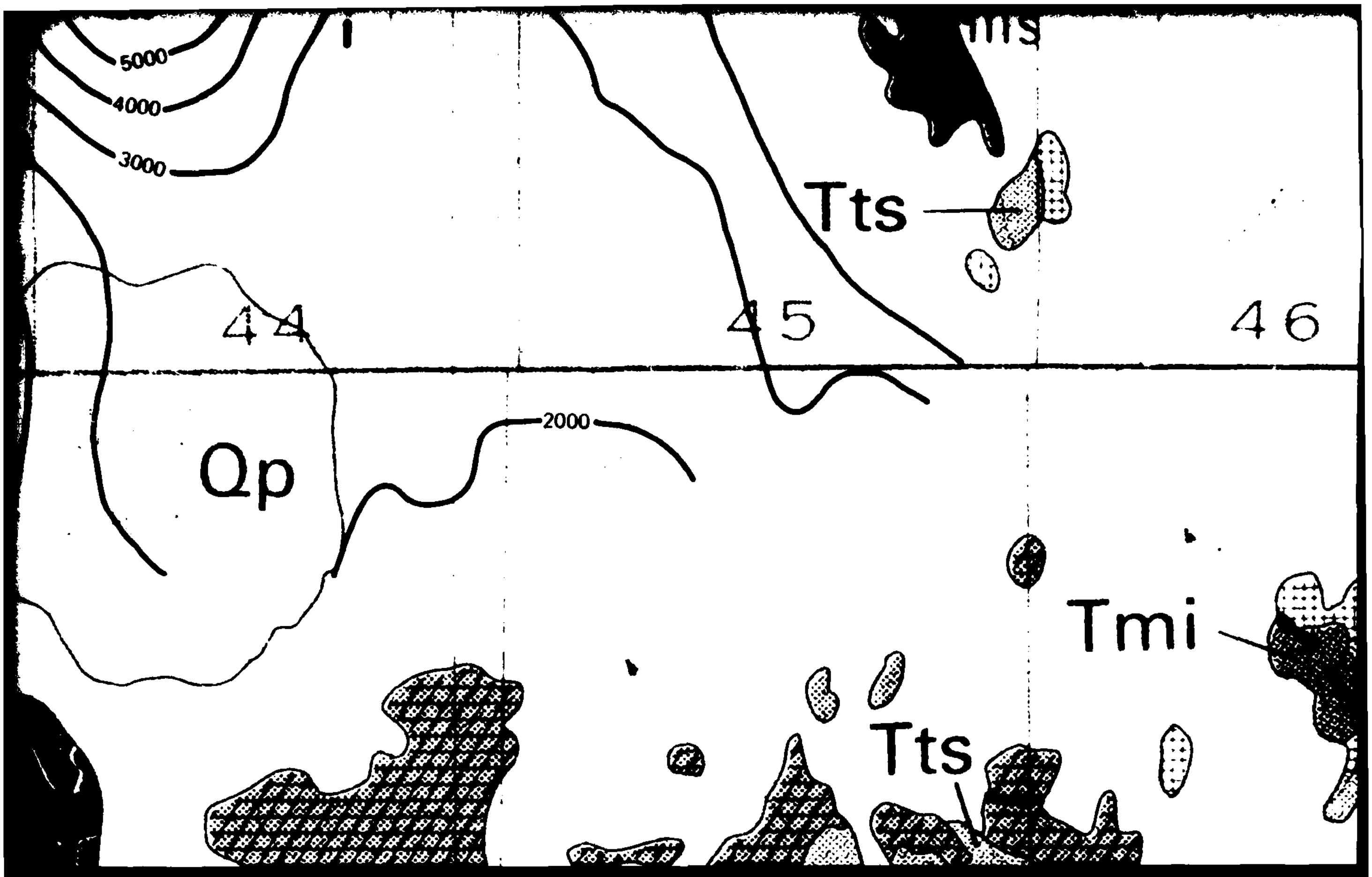

TIONS

S MAP

NORTH

SCALE 1: 125,000

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STATUTE MILES

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KILOMETERS

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RES

CARLSON(1978)

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MX SITING INVESTIGATION
DEPARTMENT OF THE AIR FORCE
BMO/AFRCE-MX

DEPTH TO ROCK INTERPRETED
FROM GRAVITY DATA
RALSTON VALLEY, NEVADA

DATE
FILMED

8